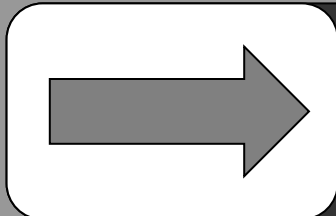


Wed Oct 1st 2014.

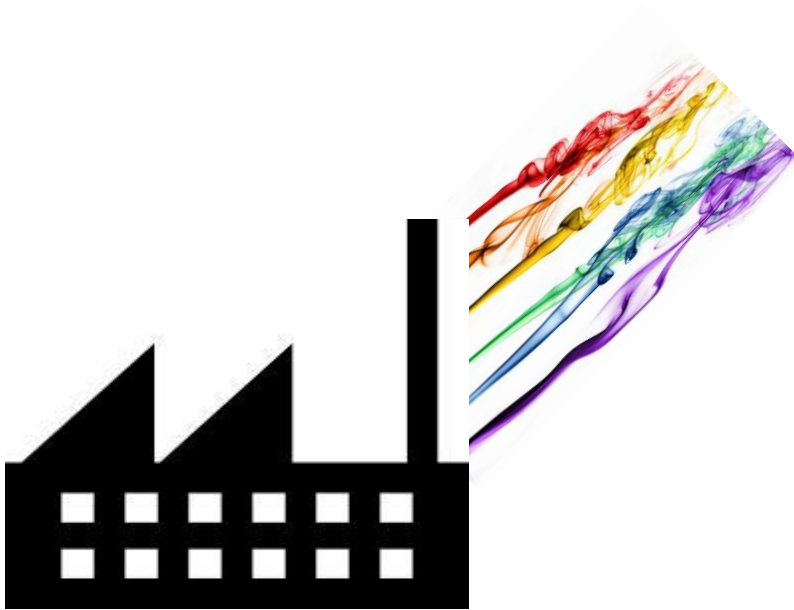
CIVL 498C Life Cycle Assessment

Week 6: Impact Assessment



slide to unlock

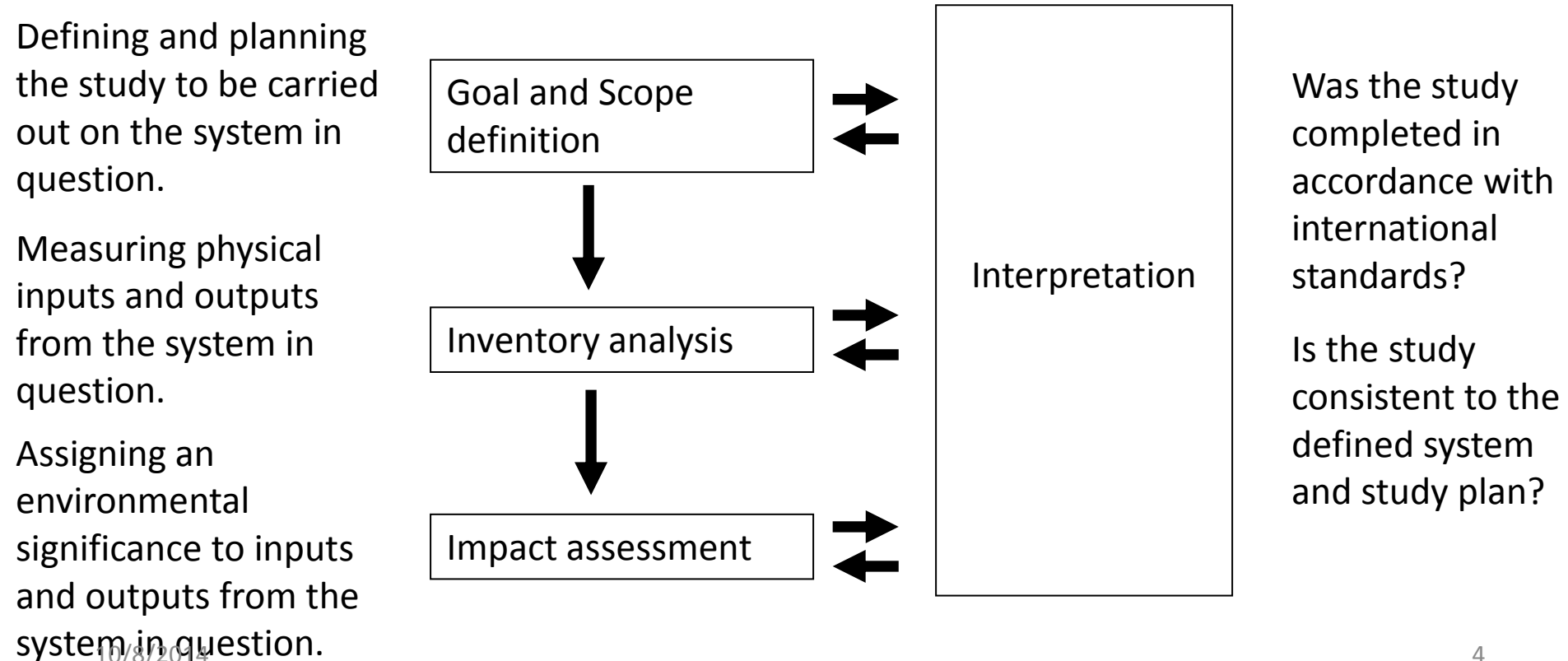
Impact Assessment



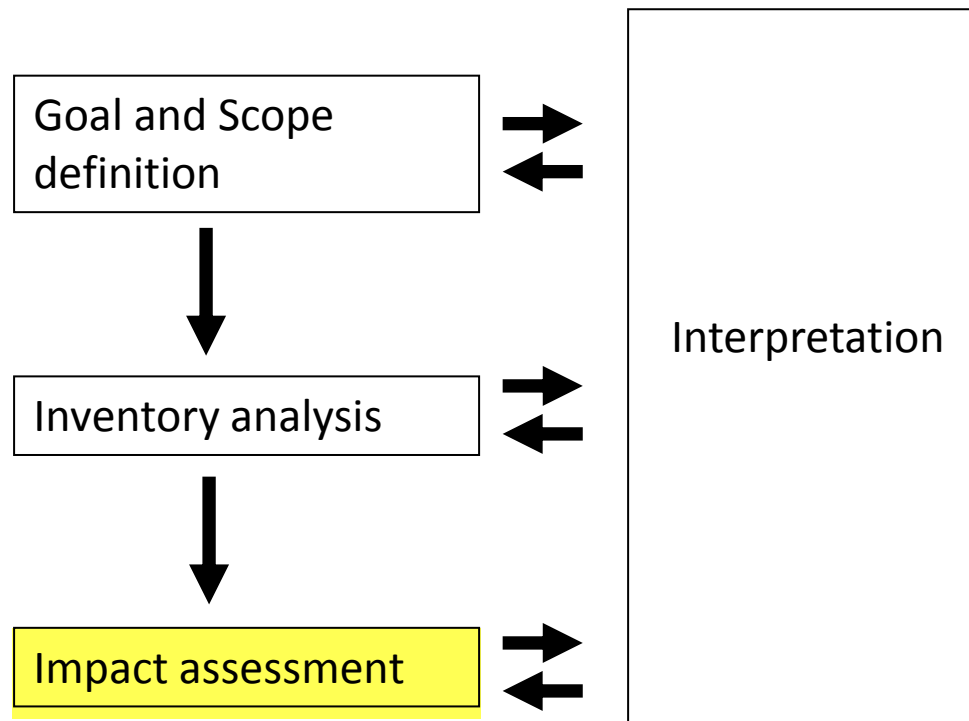
Presentation Outline

- 1. What is Impact Assessment?**
2. Impact Assessment framework.
3. Impact Category descriptions.
4. Impact Aversion Survey.

ISO LCA Methodological Framework



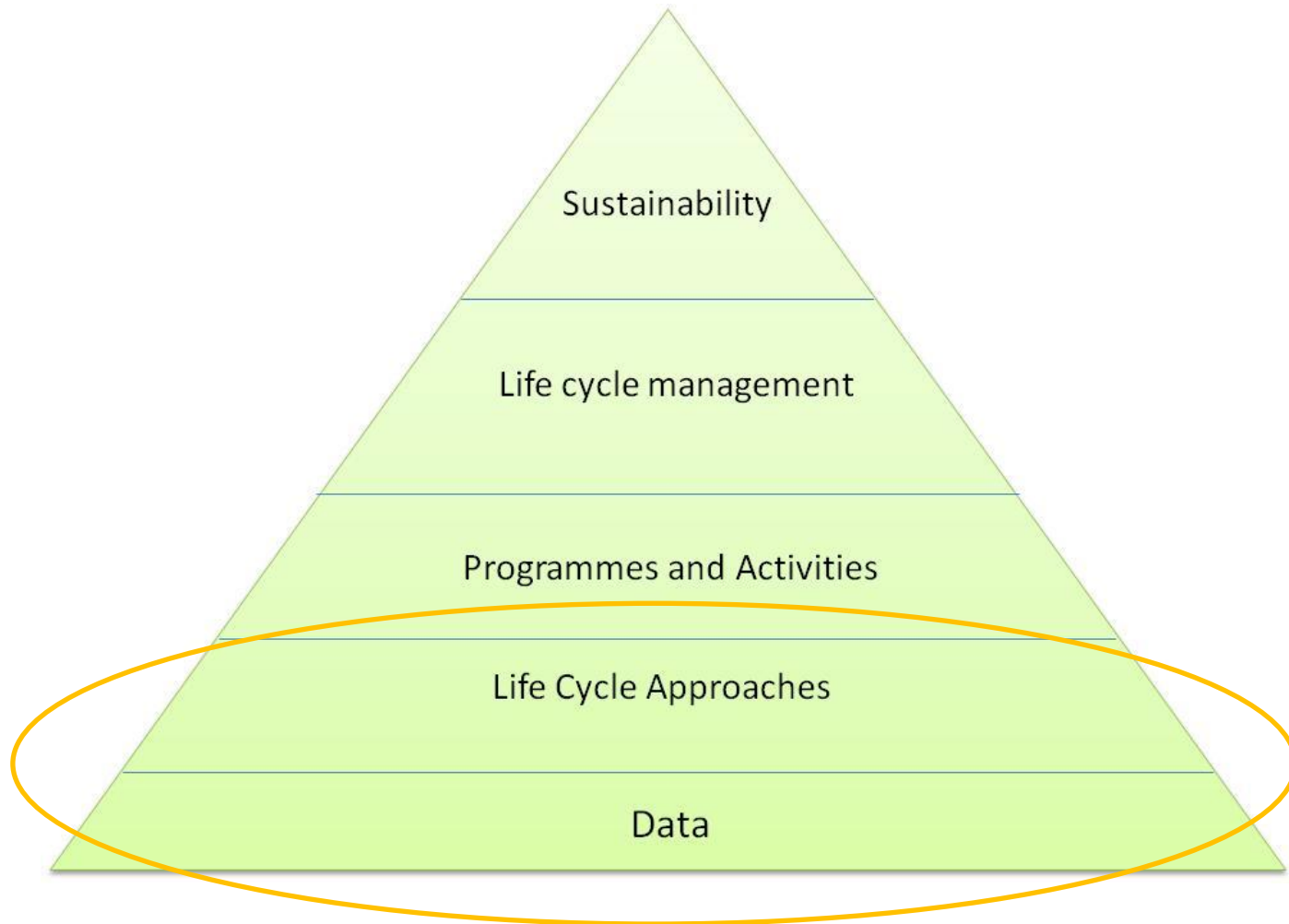
ISO LCA Methodological Framework



Assigning an environmental significance to inputs and outputs from the system in question.

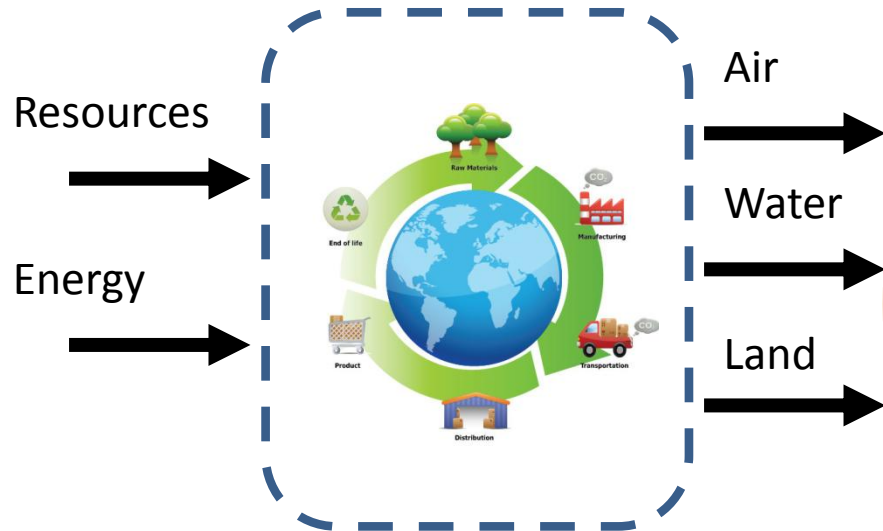
10/8/2014

UNEP/SETAC Sustainability Framework



Life Cycle Approaches

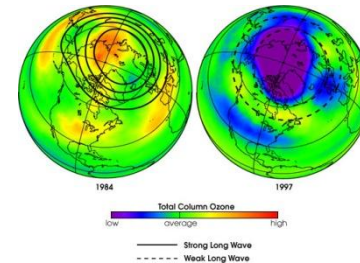
Inventory Analysis



Impact Assessment



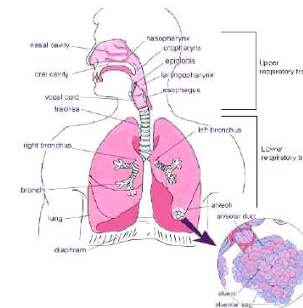
kg CO₂ eq



kg CFC-11 eq



kg SO₂ eq



kg PM₁₀ eq



kg N eq



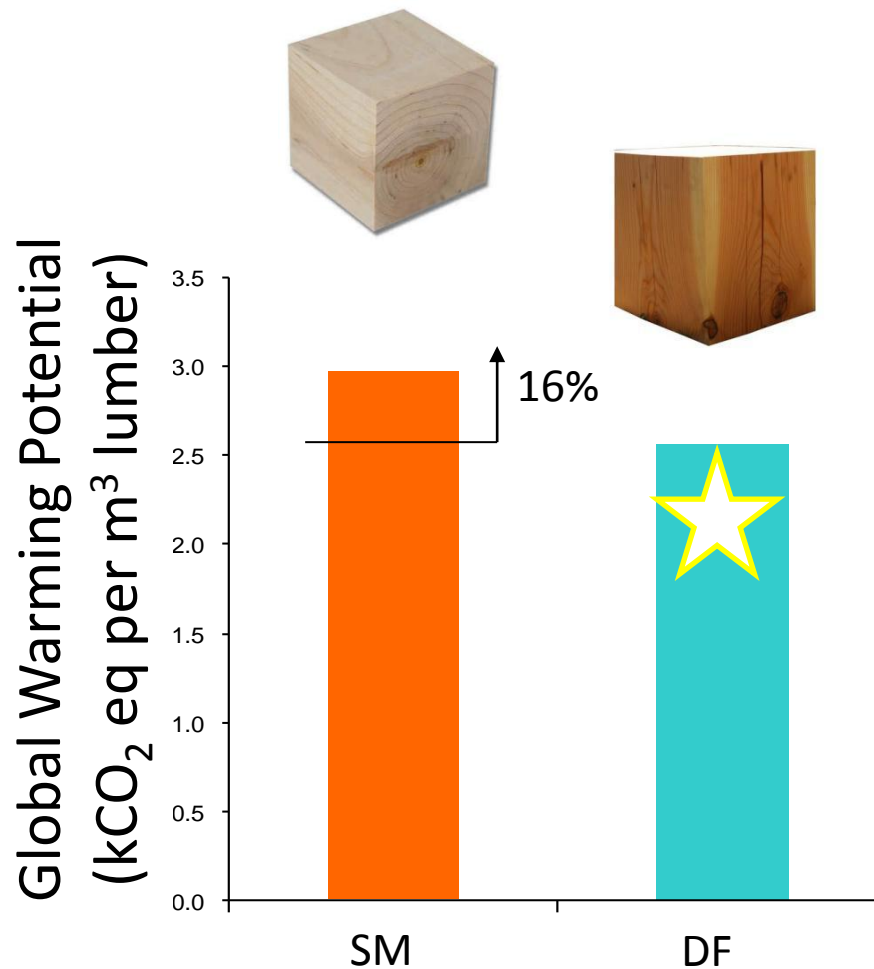
kg O₃ eq

Presentation Outline

1. What is Impact Assessment?
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LCIA Results

(Life Cycle Impact Assessment)



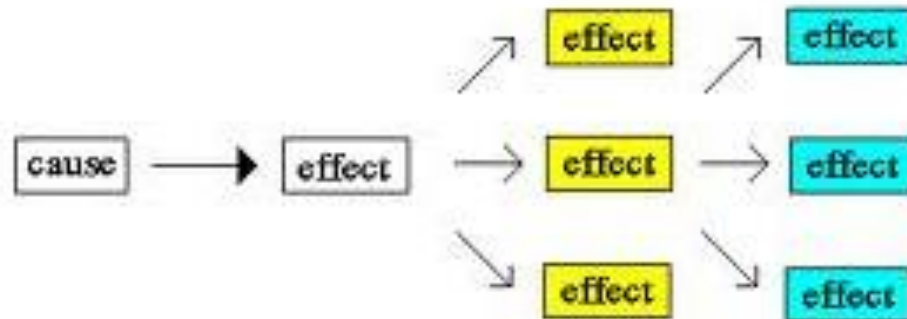
Impact Assessment	
SM	DF
GWP	
1.40	1.00
1.57	1.57
2.97	2.57

Impact Assessment Procedure

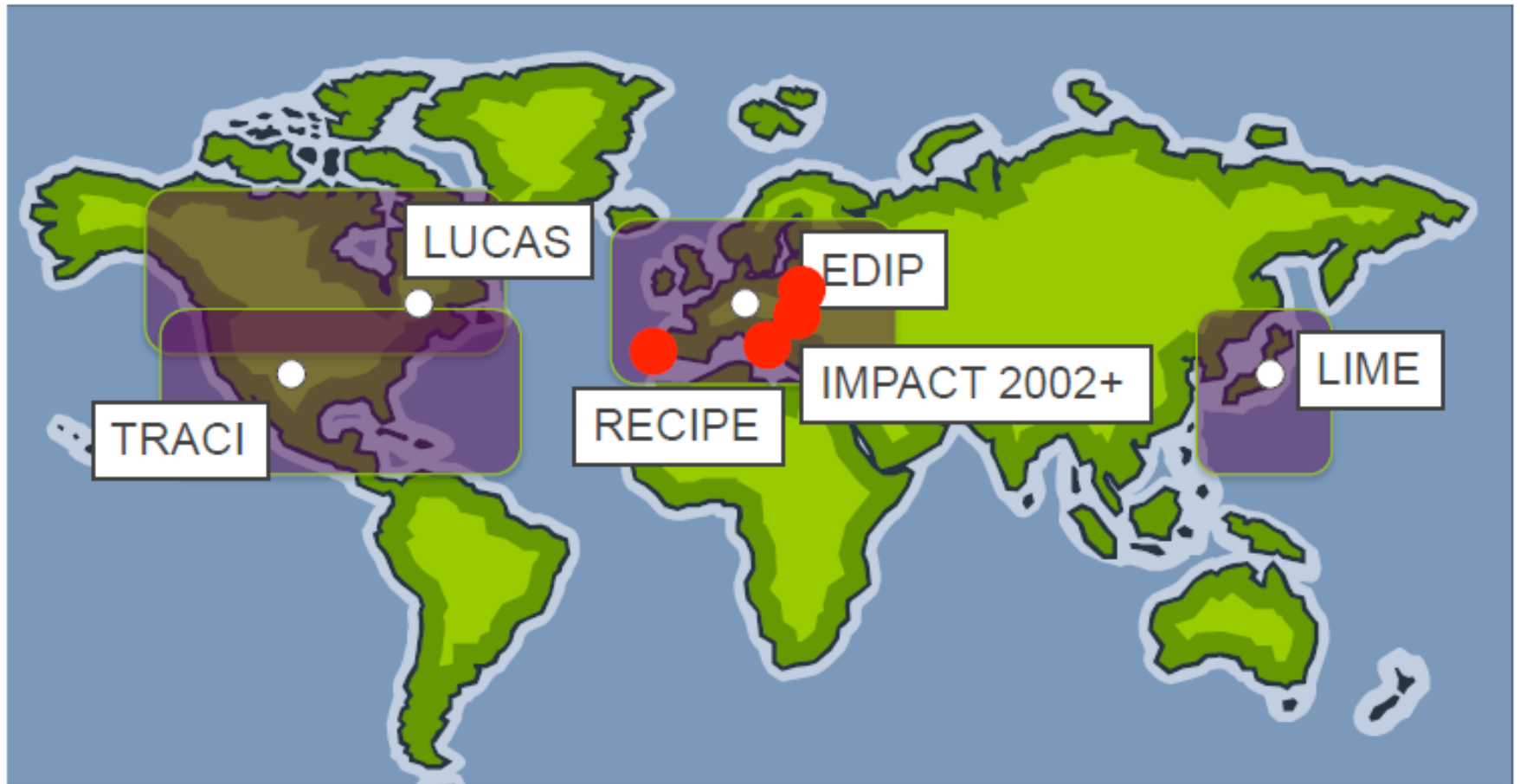
- Determine environmental impacts relevant in Goal & Scope.
- Identification and selection of
 - Impact categories – ex. Global Warming Potential
 - Category indicator – ex. kg CO₂ equivalent
 - Characterization model – ex. Calculated from baseline model of 100 years from IPCC

Characterization

- Sizes of environmental impacts are calculated per *impact category* using *characterization factors* defined, relative to *category indicators*, while modeling the cause-effect chain.



Impact Assessment Methods



Impact Assessment Methods

Impact Assessment Methodology	Method description	Website Access Point
Eco-indicator 99	Damage approach, including Normalization and default weighting sets	www.pre.nl/eco-indicator99/
EDIP97	Midpoint method with normalization	http://ipt.dtu.dk/~mic/Projects.htm#EDIP97
EDIP2003	Midpoint method with normalization	http://ipt.dtu.dk/~mic/Projects.htm#EDIP2003
EPS 2000d	Category indicators at damage level + weighting as WTP to avoid damage	http://eps.esa.chalmers.se/
(Dutch) LCA Handbook	Midpoint method with normalization	http://www.leidenuniv.nl/cml/ssp/projects/lca2/lca2.html
IMPACT 2002(+)	Midpoint + damage including normalization	http://www.epfl.ch/impact
ReCiPe	Midpoint + damage including normalization	www.lcia-recipe.info/
(SWISS) ECOSCARCITY	Weighting method, based on environmental policy goals, to be used for midpoint categories and selected emissions/interventions	http://www.umwelt-schweiz.ch/buwal/eng/fachgebiete/fg_produkte/umsetzung/oekobilanzen/index.html
JEPIX	Weighting method, based on distance-to-target of environmental policy. Providing regionalized weighting factors based on specific environmental quality.	www.jepix.org
TRACI	Midpoint method with normalization	http://epa.gov/ORD/NRMRL/std/sab/iam_traci.htm

Impact Estimator's Impact Assessment

Characterized by	Midpoint Impact	Category Indicator
IPCC	Global warming potential	kg CO ₂ eq
WMO	Ozone depletion potential	kg CFC ⁻¹¹ eq
US EPA	Eutrophication potential	kg N eq
US EPA	Acidification potential	kg SO ₂ eq
US EPA	Smog formation potential	kg O ₃ eq
US EPA	Human health respiratory effects potential	kg PM _{2.5} eq
Athena Institute	Total Primary, Non-renewable, Fossil Fuel Consumption	MJ

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Global Warming Potential

- Category indicator
 - kg CO₂e
- Characterized by
 - Intergovernmental Panel on Climate Change (IPCC)
- Midpoint impact
 - Capacity to absorb infrared radiation, which heats the atmosphere

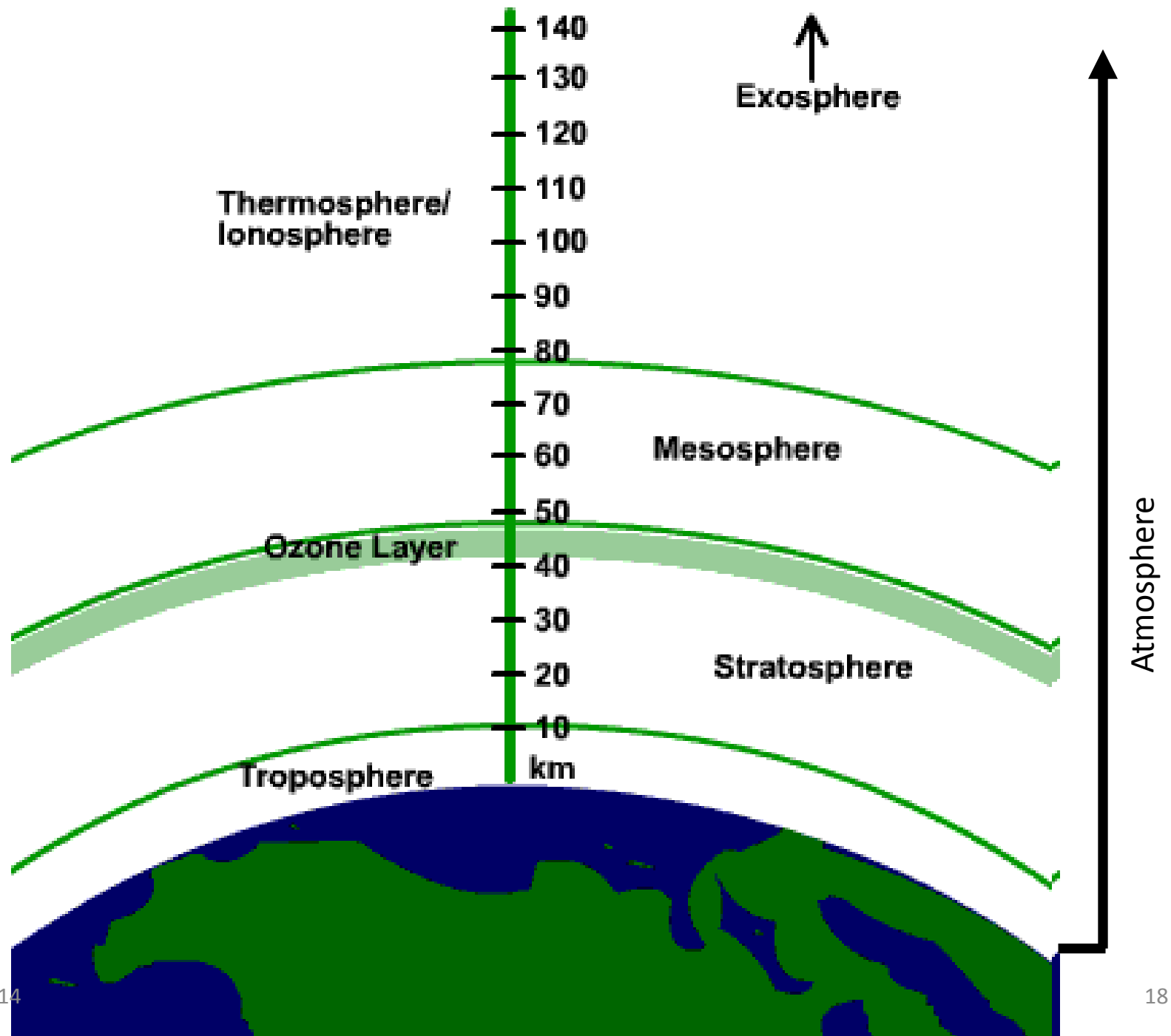


$$GWP_{T,i} = \int a_i c_i(t) dt / \int a_{CO_2} c_{CO_2}(t) dt$$

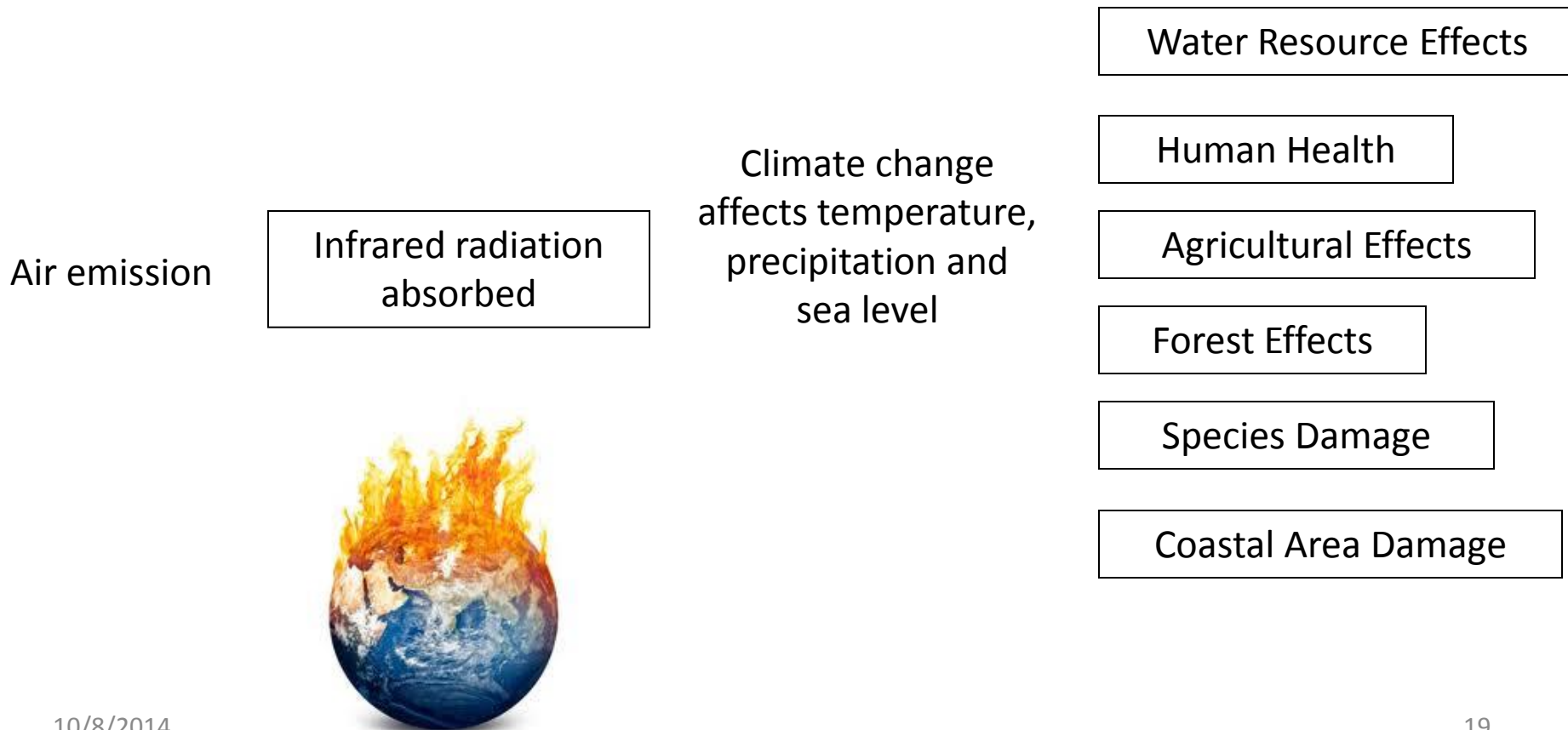
a_i = radiative forcing per unit concentration increase of GHG i (W/m²kg)

$C_i(t)$ = concentration of GHG i at time T after release (kg/m³)

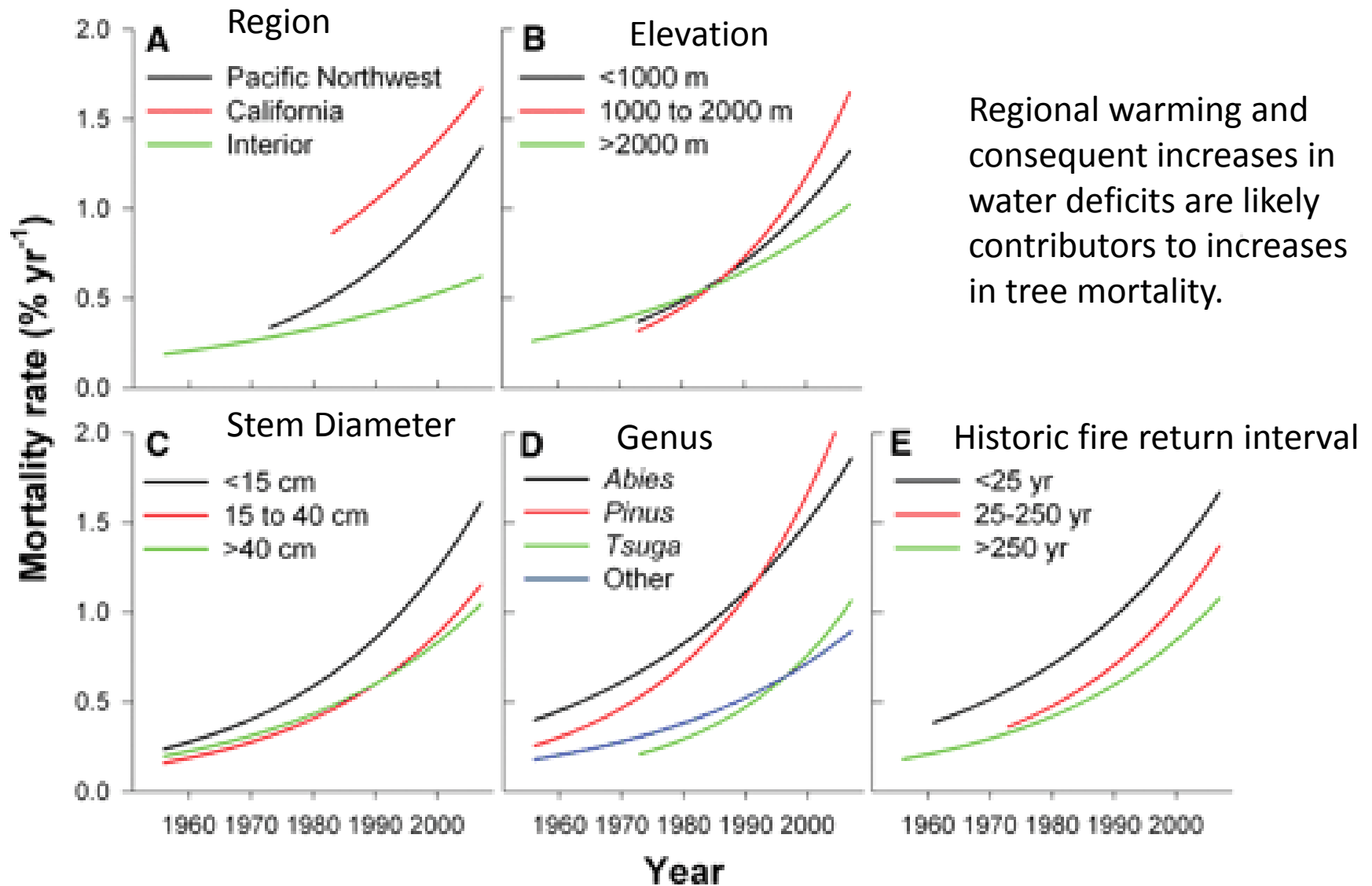
t = time over which integration is performed (year) → IPCC uses 100 years



GWP – Cause Effect Chain



ex. Forest Endpoint Effects

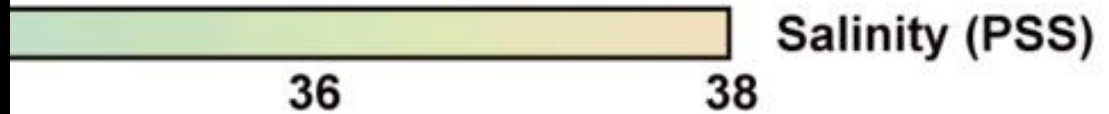
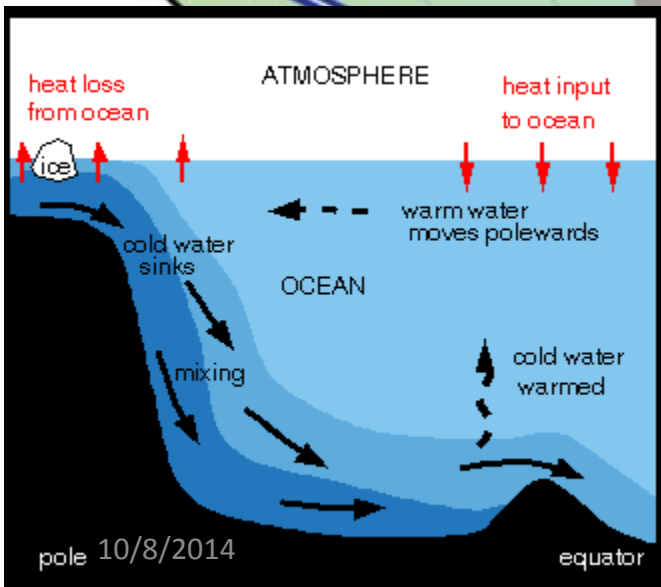
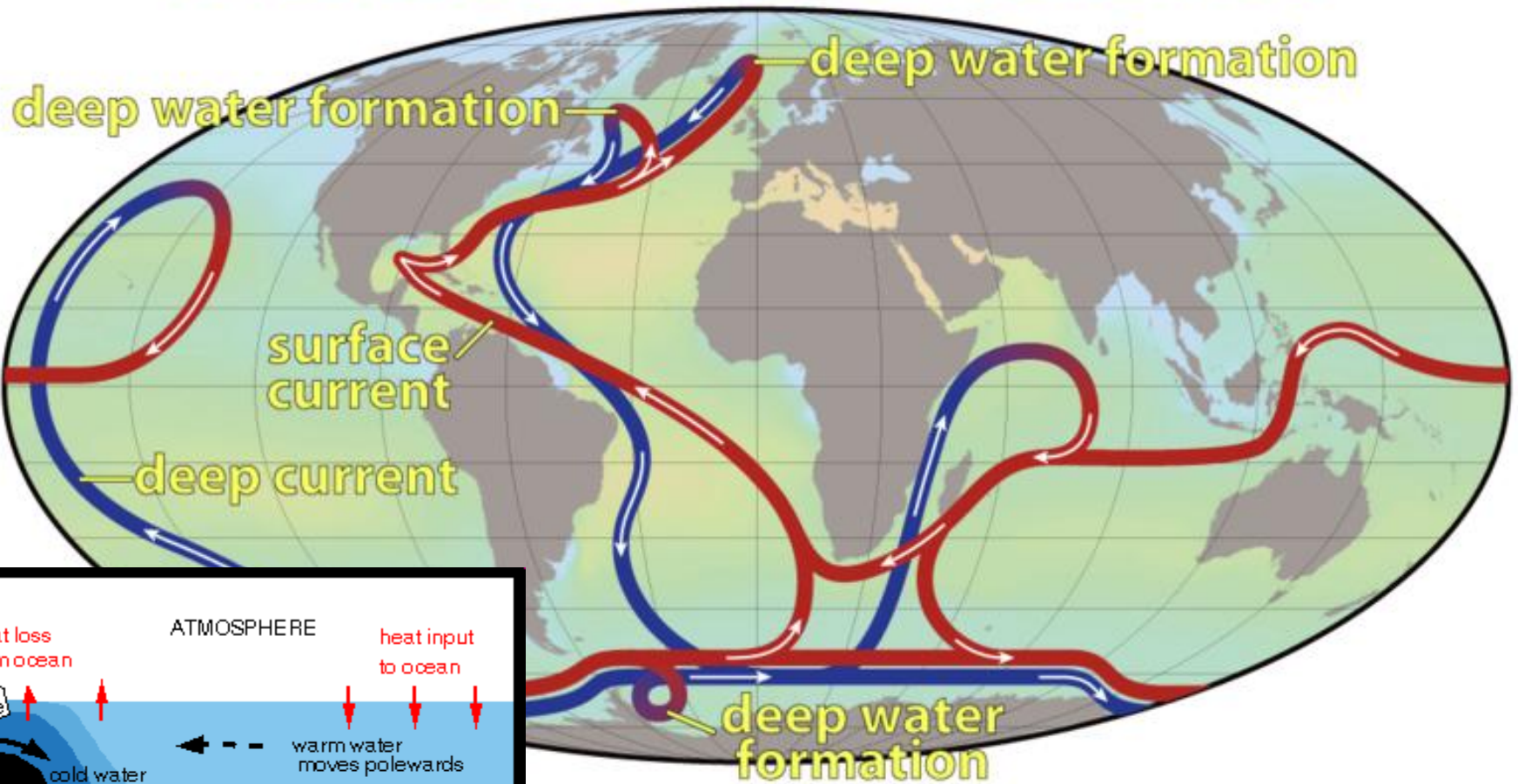


van Mantgem, P.J., Stephenson, N.L., Byrne, J.C., Daniels, L.D., Franklin, J.F., Fulé, P.Z., Harmon, M.E., Smith, J.M., Taylor, A.H. and Veblen, T.T. (2009), Widespread increase of tree mortality rates in the western United States., *Science*, 0, 0

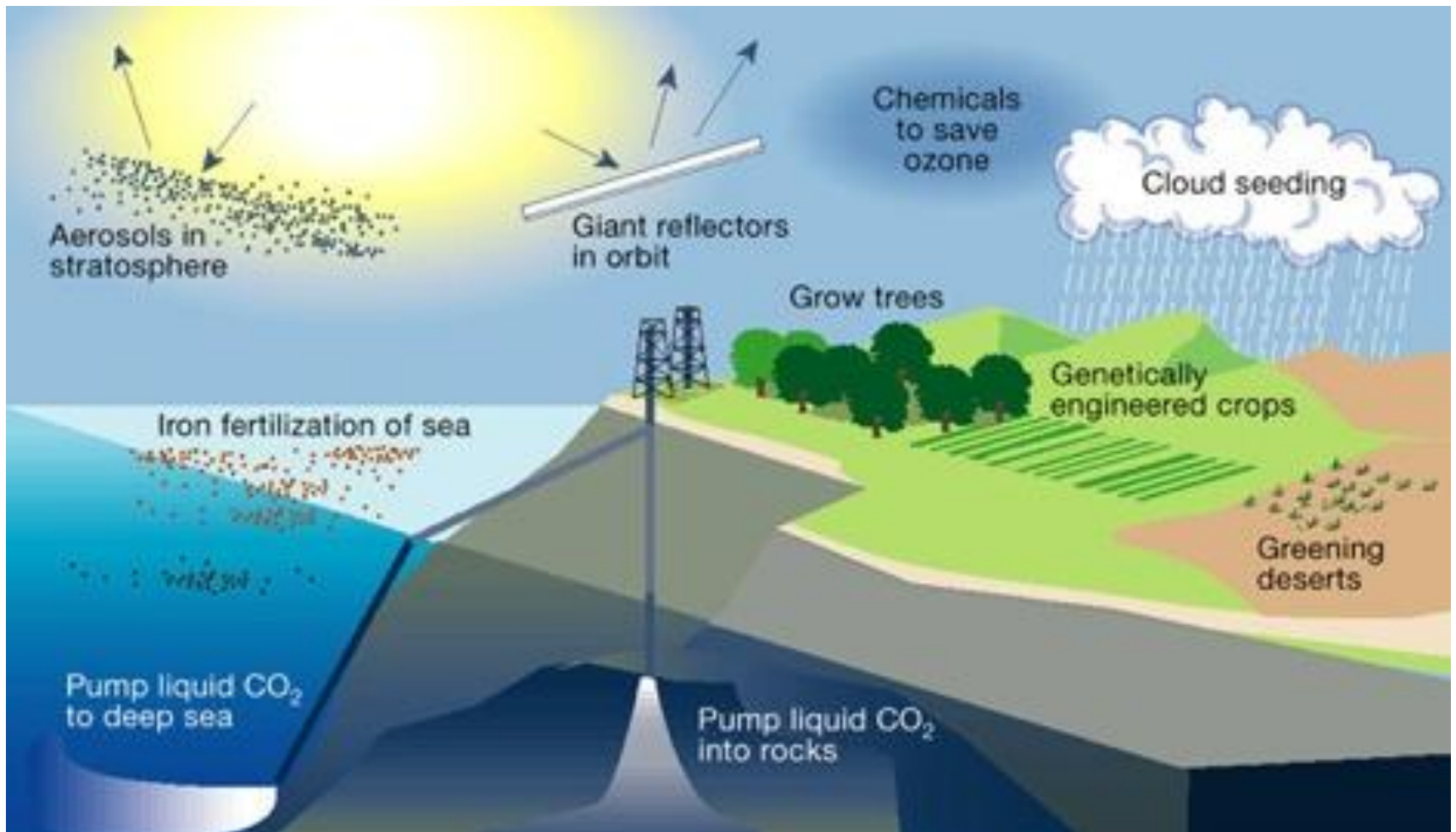
Intergovernmental Panel on Climate Change

- Recent Report
 - <http://www.ipcc.ch/>
- YouTube clip
 - <http://www.youtube.com/watch?v=HF9LNuH3IpU&feature=youtu.be>

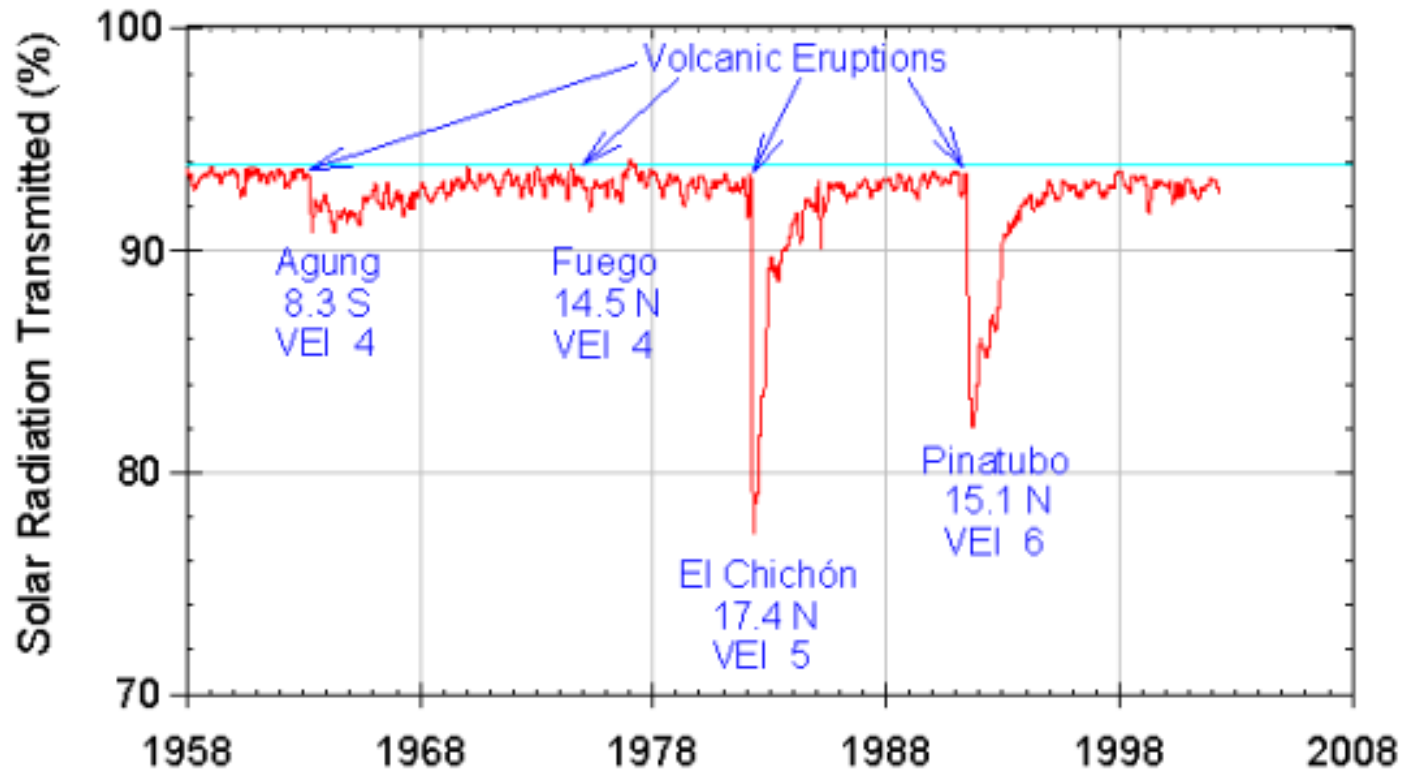
Thermohaline Circulation



Negative GWP? - Geoengineering



Volcanoes can be cool!?



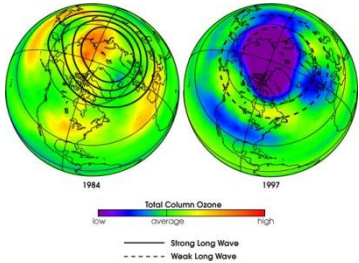
Check out

”David Keith’s unusual climate change idea” on TED.com



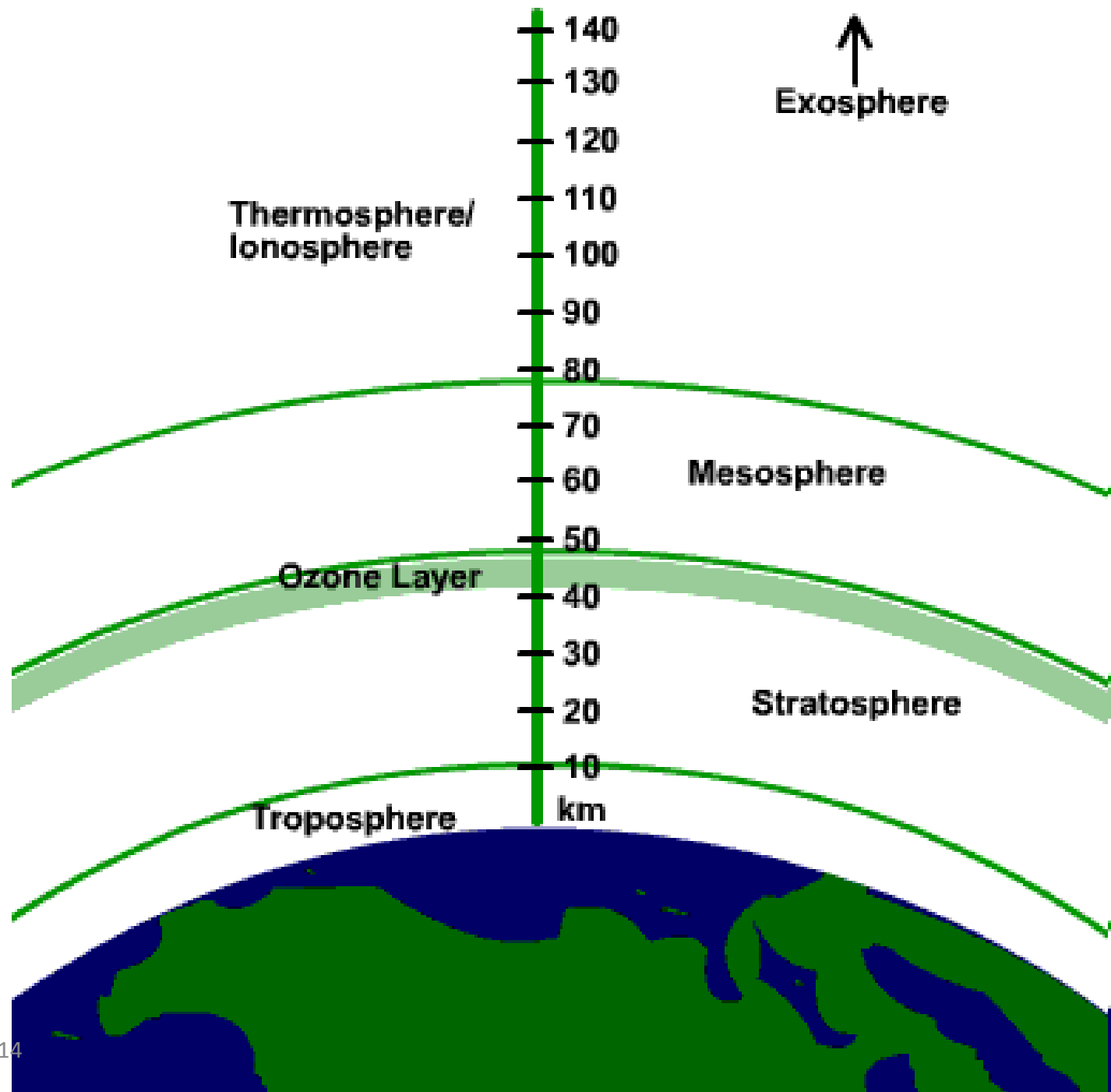
Ozone Depletion Potential

- Category indicator
 - kg CFC⁻¹¹ eq
- Characterized by
 - World Meteorological Organization (WMO)
- Midpoint impact
 - Potential to change stratospheric ozone column, at steady-state, due to amount of emission of substance i relative to that of CFC⁻¹¹



$$\text{ODP}_i = \delta [\text{O}_3]_i / \delta [\text{O}_3]_{\text{CFC-11}}$$

$\delta [\text{O}_3]_i$ = change in the ozone column for substance i



ODP – Cause Effect Chain

Air emission

Reduction of Ozone
Layer

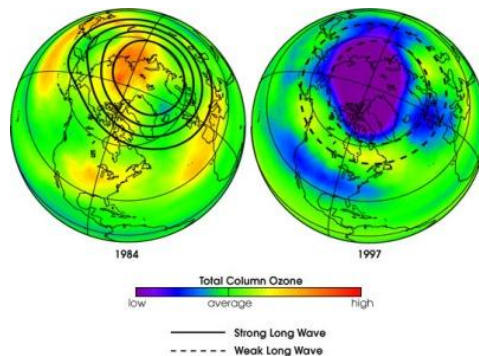
Increased UVB
reaching Earth

Agricultural Effects

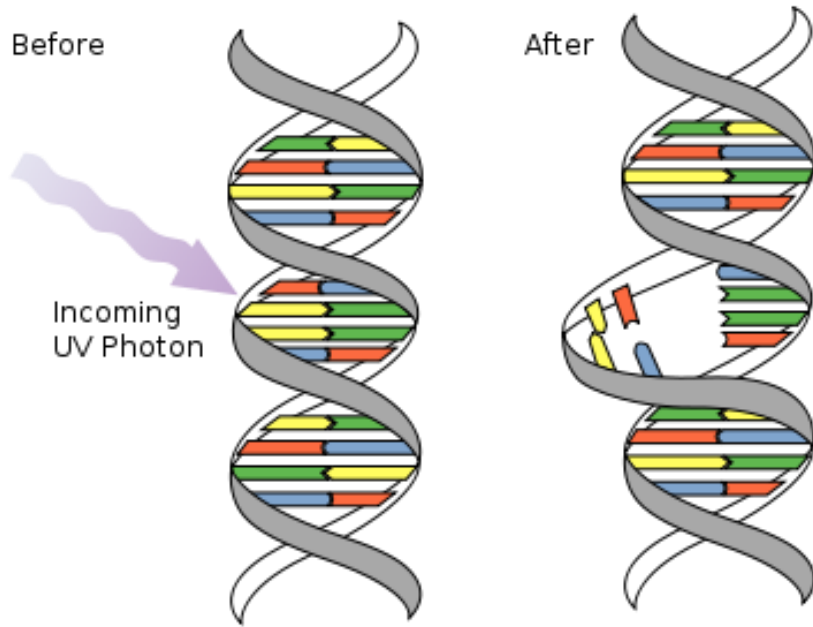
Human health

Species Damage

Material Damage



ex. ODP Endpoint Effects



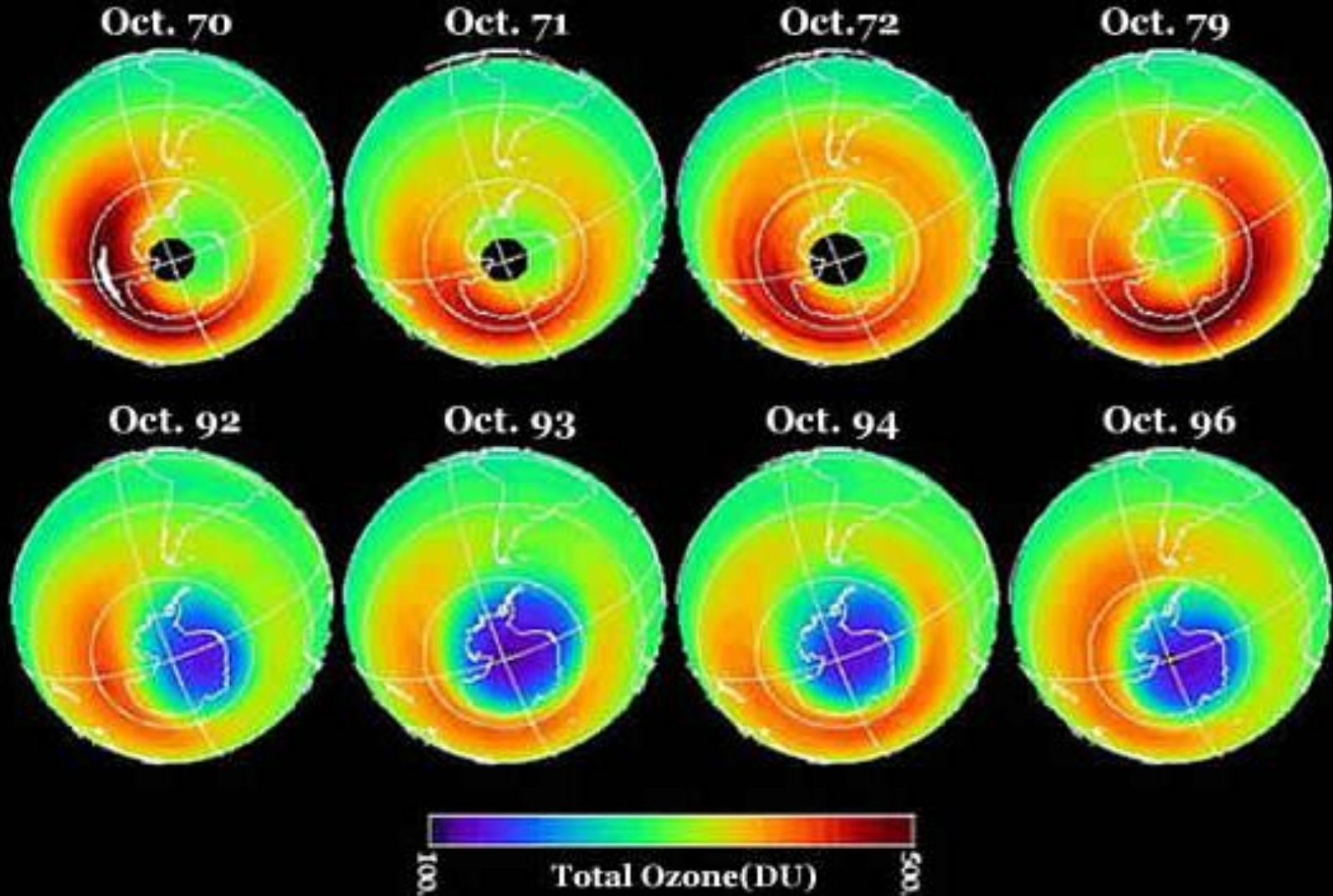
http://commons.wikimedia.org/wiki/File:DNA_UV_mutation.gif



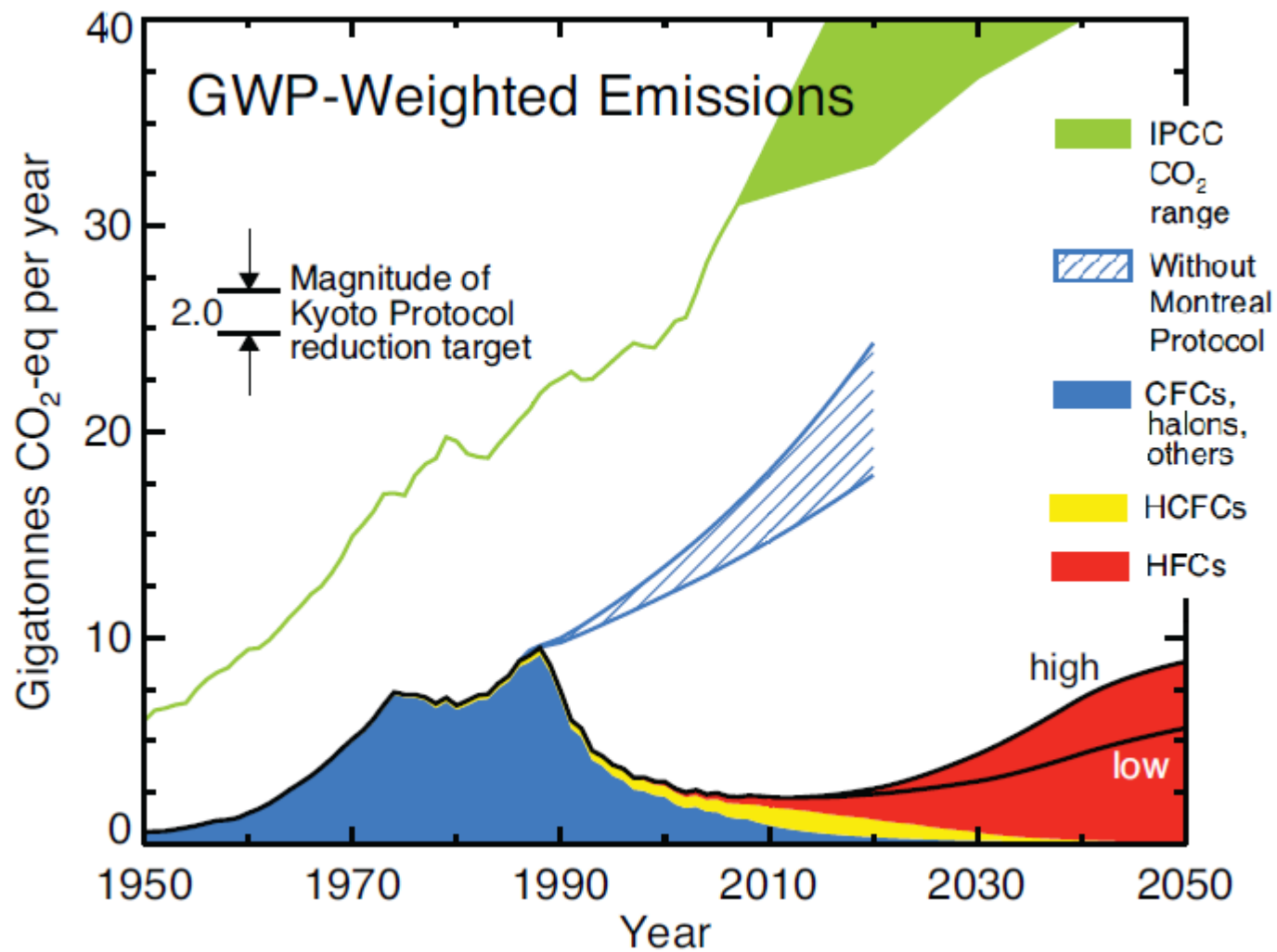
http://www.ehow.com/list_6716266_effects-ultraviolet-light-plants_-growth.html



BUV & TOMS total ozone



Source - http://www.landcareresearch.co.nz/research/ecosystems/penguins/antarctic_features.asp
10/8/2014



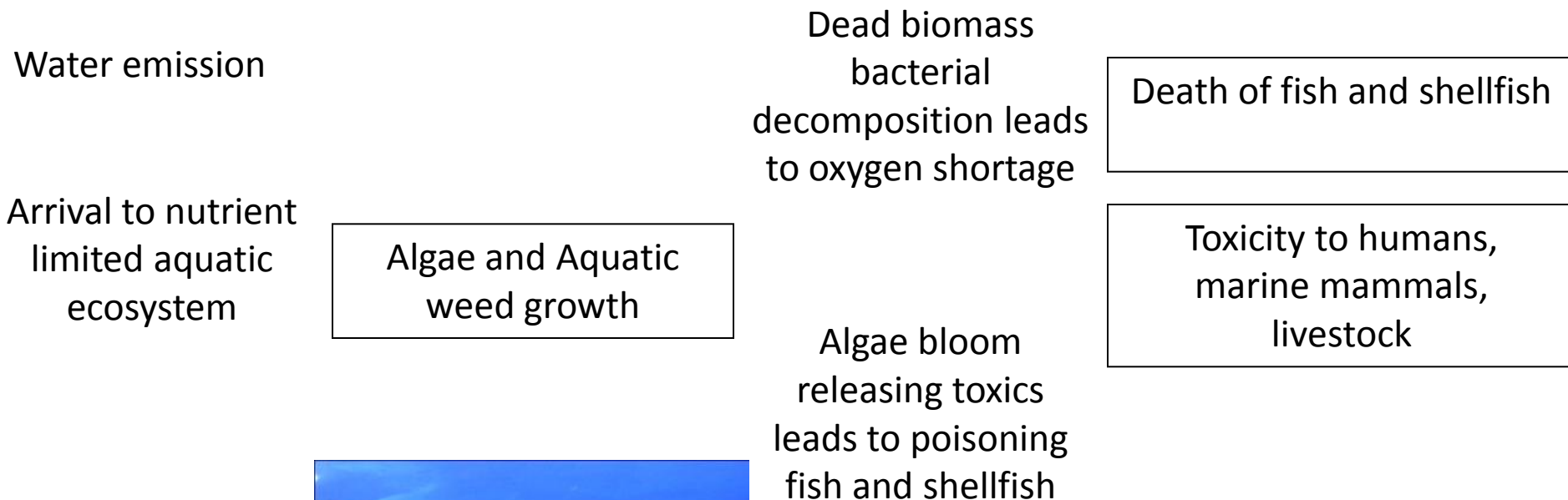


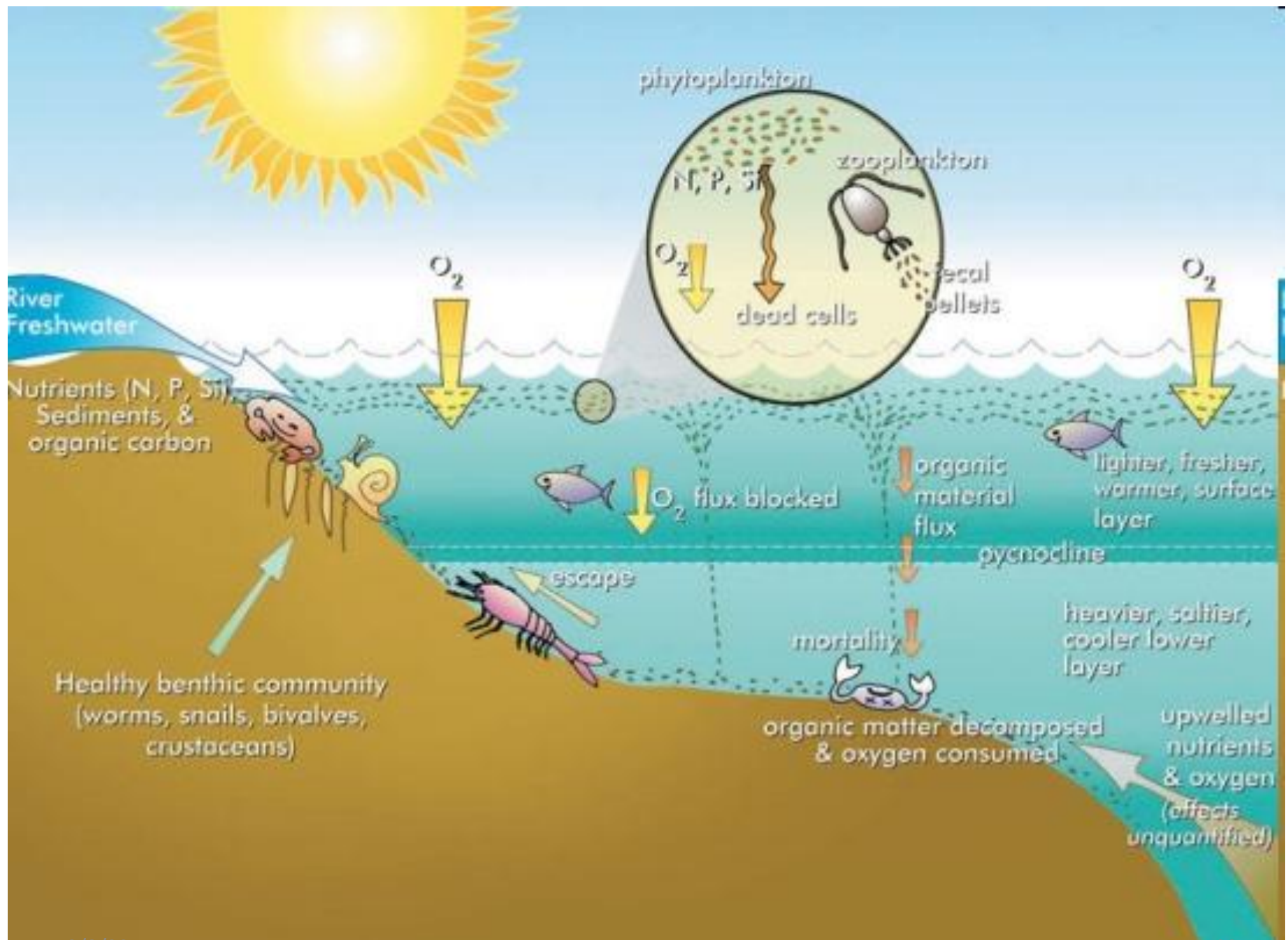
Eutrophication Potential



- Category indicator
 - kg N eq
- Characterized by
 - US EPA
- Midpoint impact
 - Influence on algae growth in nutrient deficient surface waters
 - Relative to algae growth in photic zone of aquatic ecosystem as result of 1kg of Nitrogen
 - Takes into account transport and probability of arriving in aquatic environment

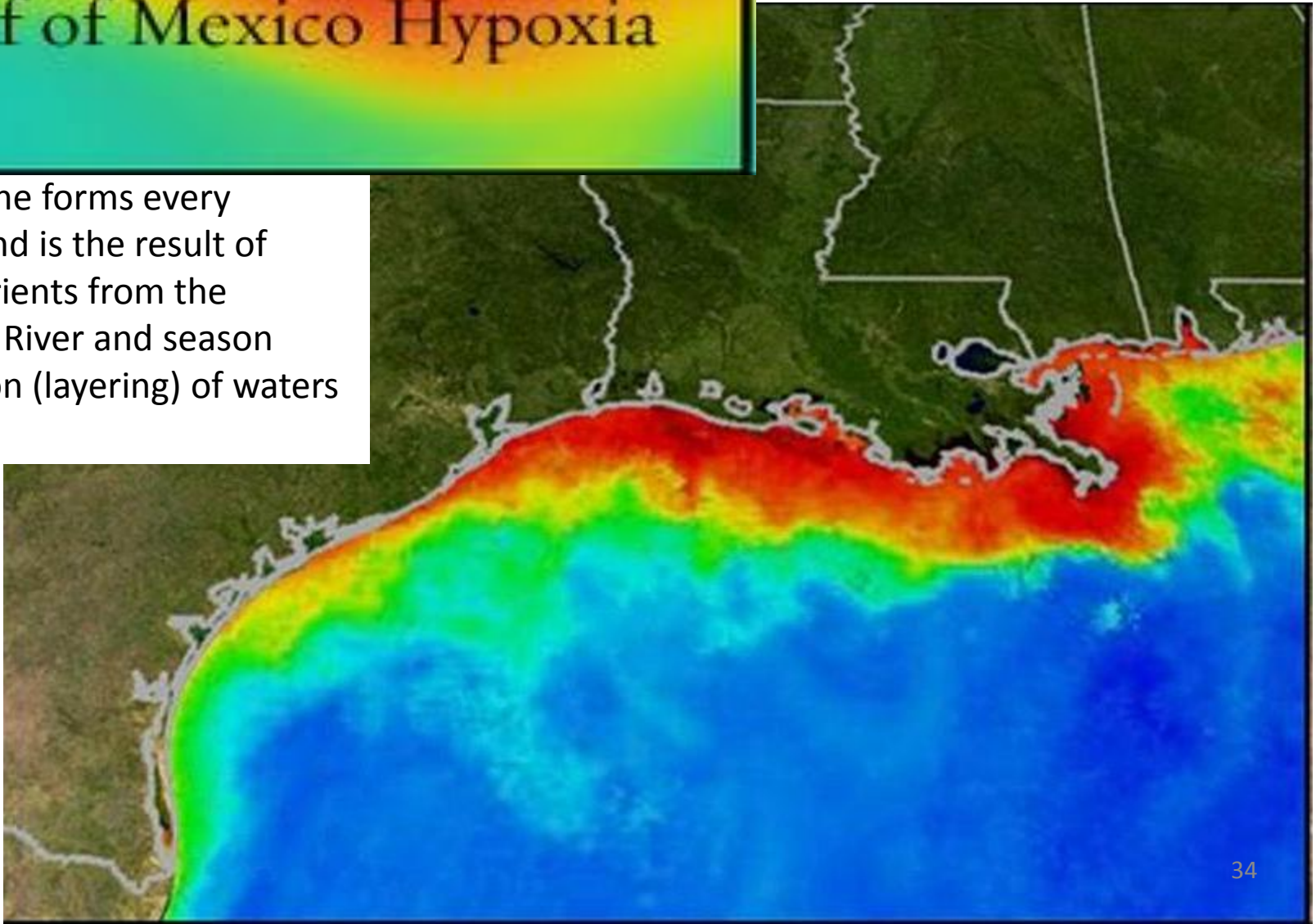
EP – Cause Effect Chain





The Dead Zone: Gulf of Mexico Hypoxia

Hypoxic zone forms every summer, and is the result of excess nutrients from the Mississippi River and season stratification (layering) of waters in the Gulf.



Hypoxia Around the World

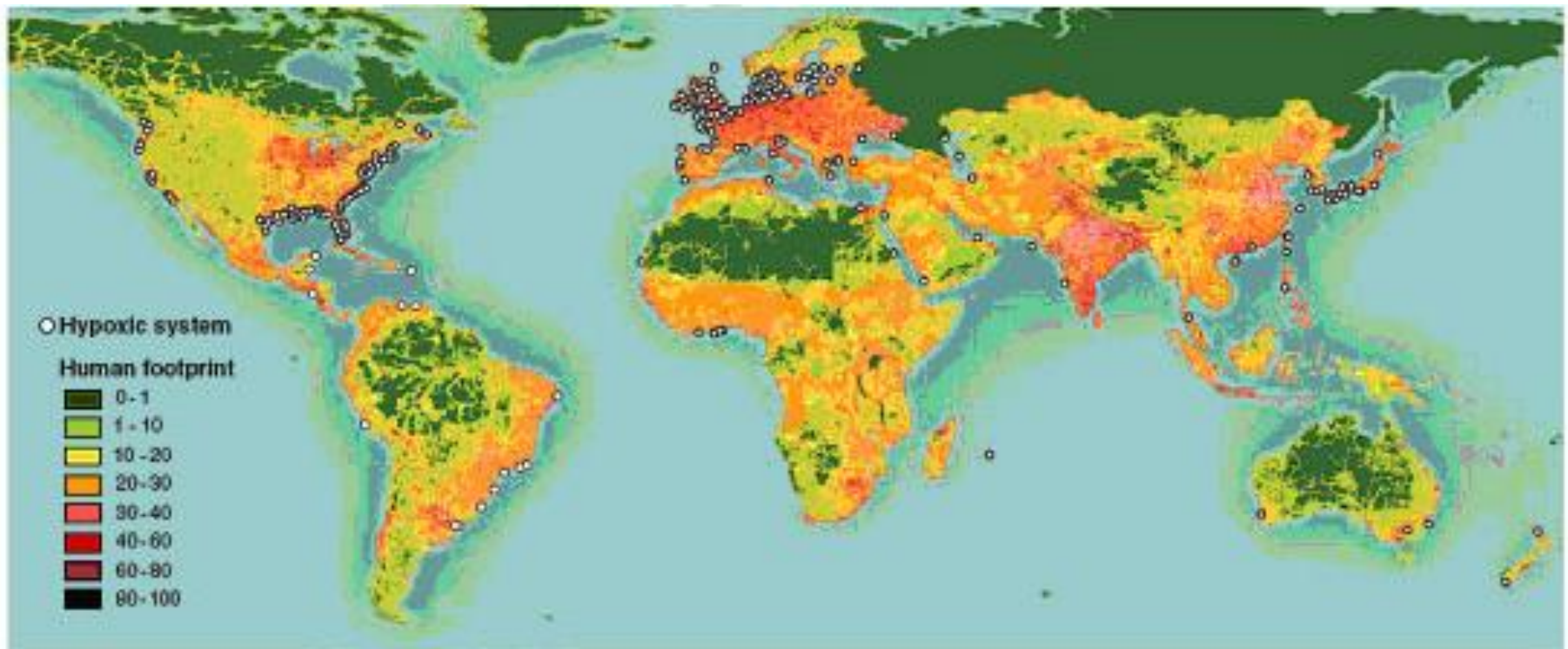


Fig. 1. Global distribution of 400-plus systems that have scientifically reported accounts of being eutrophication-associated dead zones. Their distribution matches the global human footprint [the normalized human

influence is expressed as a percent (41)] in the Northern Hemisphere. For the Southern Hemisphere, the occurrence of dead zones is only recently being reported. Details on each system are in tables S1 and S2.



Acidification Potential



- Category indicator
 - kg SO₂ eq
- Characterized by
 - US EPA
- Midpoint impact
 - Capacity to form acidifying H⁺ ions relative to SO₂, increasing the acidity of water and soil systems

(ex. from CML) $AP_i = (n_{H^+ i} / n_{H^+ SO_2})$

$n_{H^+ i}$ = number of H⁺ ions produced by substance i

AP – Cause Effect Chain

Air Emission

Emission
atmospheric
concentration,
topography,
temperature
climate

Deposition – wet, dry,
cloud



Leaching of Al leads
to ecotoxicity

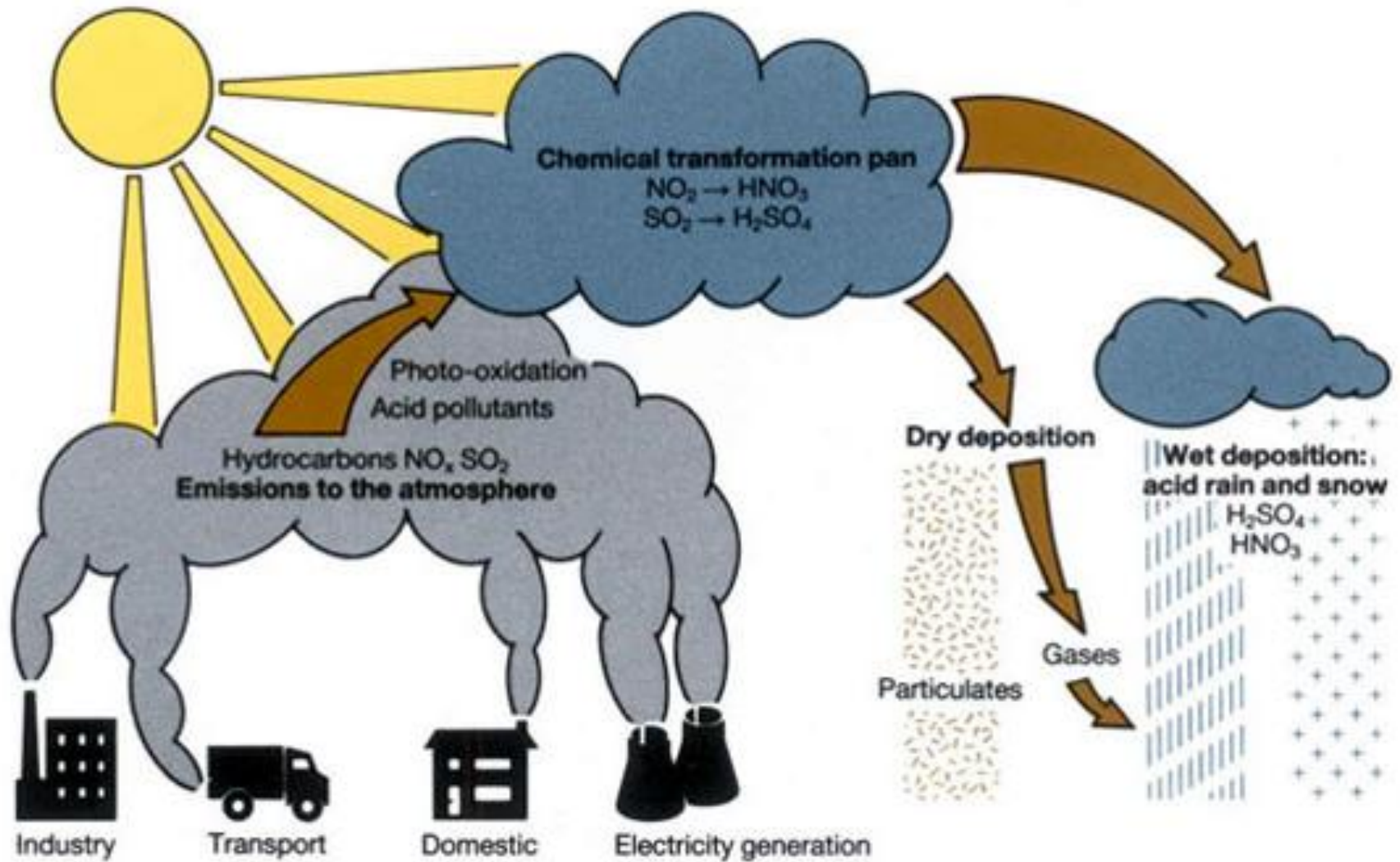
Leaching of H⁺ ions
acidifies lakes and
streams

Leaching of nutrient
cations leads to
reduced forest/plant
health

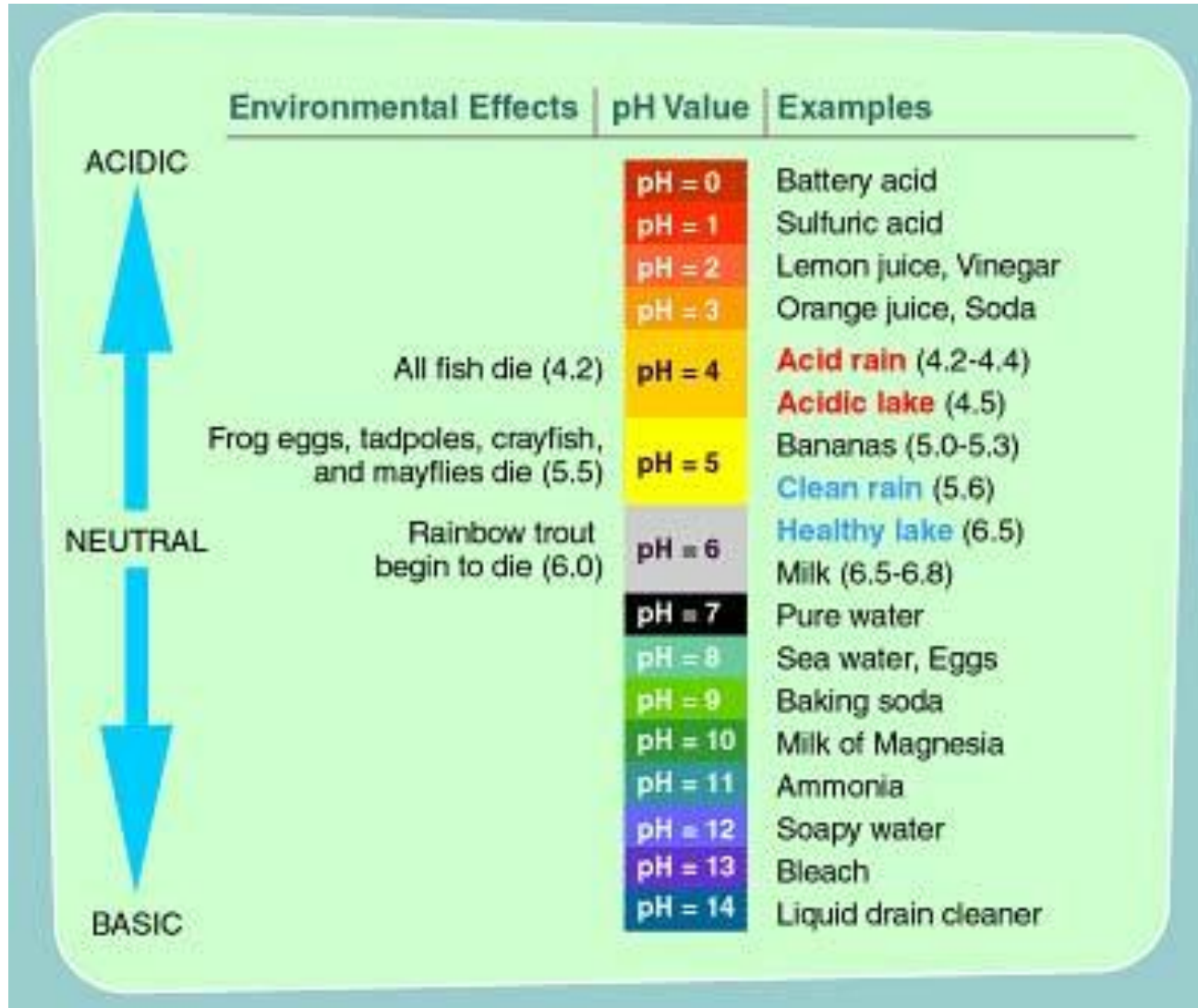
Ecosystem changes

Plant and animal
mortality

How acid rain is formed



Acidification Potential





Smog Potential

aka

Photochemical ozone formation

Photo-oxidant formation





Smog Potential

- Category indicator
 - kg O₃ eq
- Characterized by
 - US EPA
- Midpoint impact
 - A given emission's influence on the amount of ozone formed photochemically in the troposphere



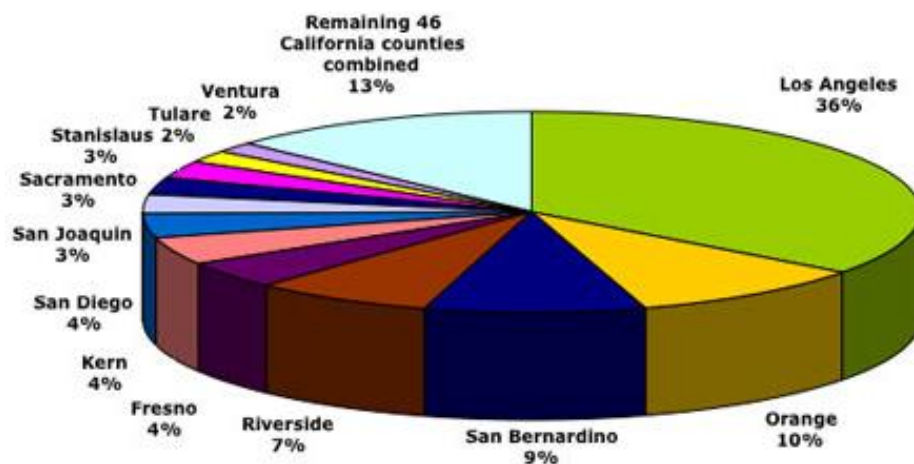
Smog Potential

- Smog contributes to
 - Emphysema
 - Bronchitis
 - Asthma

- Which can lead to
 - Missing school
 - Restricted activity
 - Hospital visits
 - Emergency visits
 - Premature death

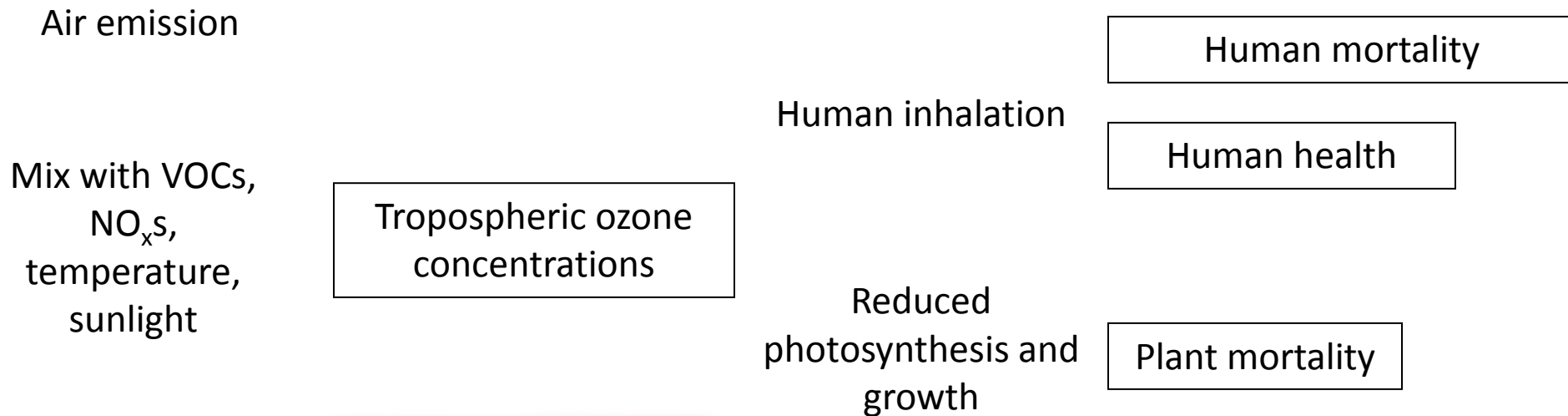
A 2005 study found that in California

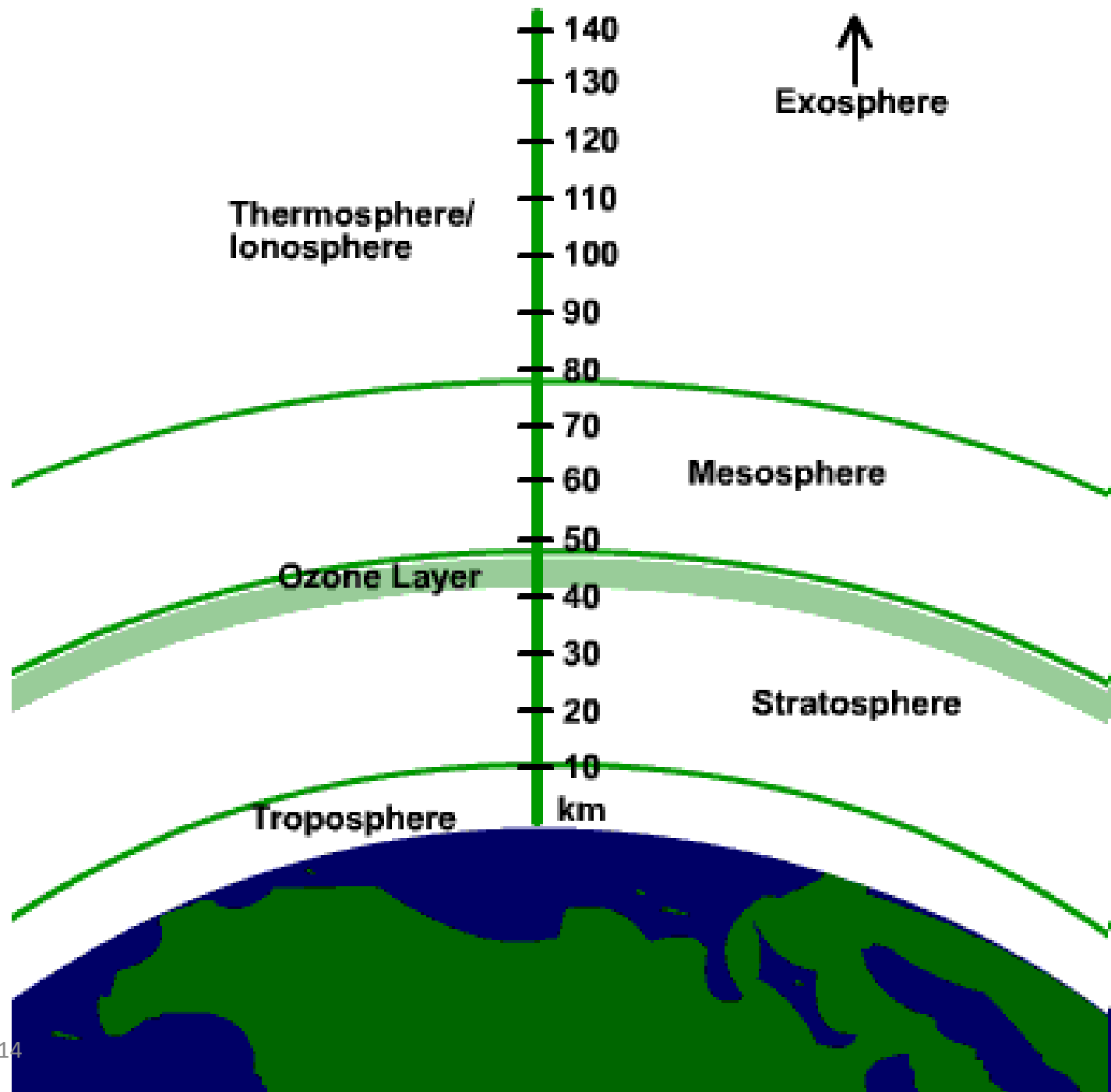
Costs of five health impacts attributed to smog pollution tops \$521 million per year



Economic costs attributed to school absences, restricted activity days for adults, respiratory hospitalizations and asthma Emergency Room visits due to smog pollution. Other smog-related effects are not included in this tally.

SP – Cause Effect Chain

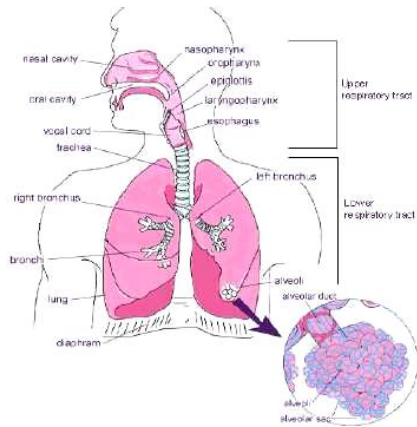






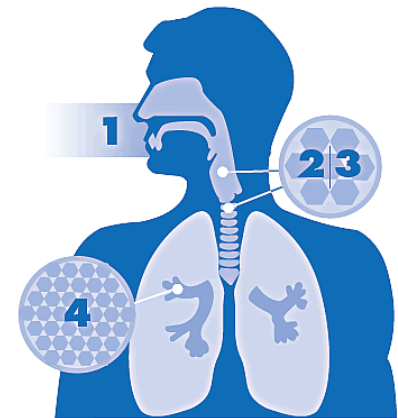
Human Health Criteria - Air

- Category indicator
 - kg PM_{2.5} eq
- Characterized by
 - US EPA
- Midpoint impact
 - Exposure to air borne particulate matter less than 10 µm in size



$$1 \text{ m} = 1,000,000 \text{ } \mu\text{m}$$

How Particulate Matter Enters Our Body



1 Particulate matter enters our respiratory (lung) system through the nose and throat.

2 | 3 The larger particulate matter (PM₁₀) is eliminated through coughing, sneezing and swallowing.

4 PM_{2.5} can penetrate deep into the lungs. It can travel all the way to the alveoli, causing lung and heart problems, and delivering harmful chemicals to the blood system.

HH-Air – Cause Effect Chain

Air emission
(inhaled by
human)

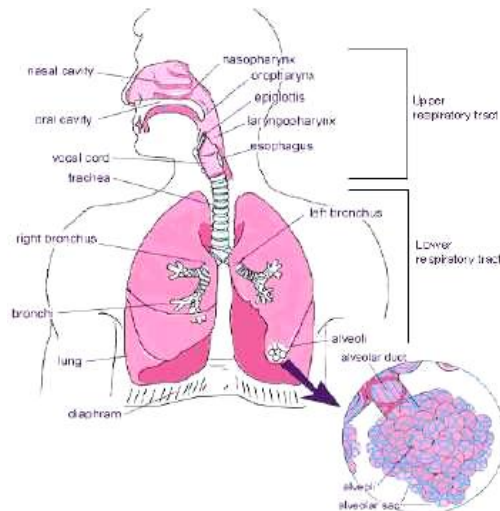
PM deposition in
alveoli

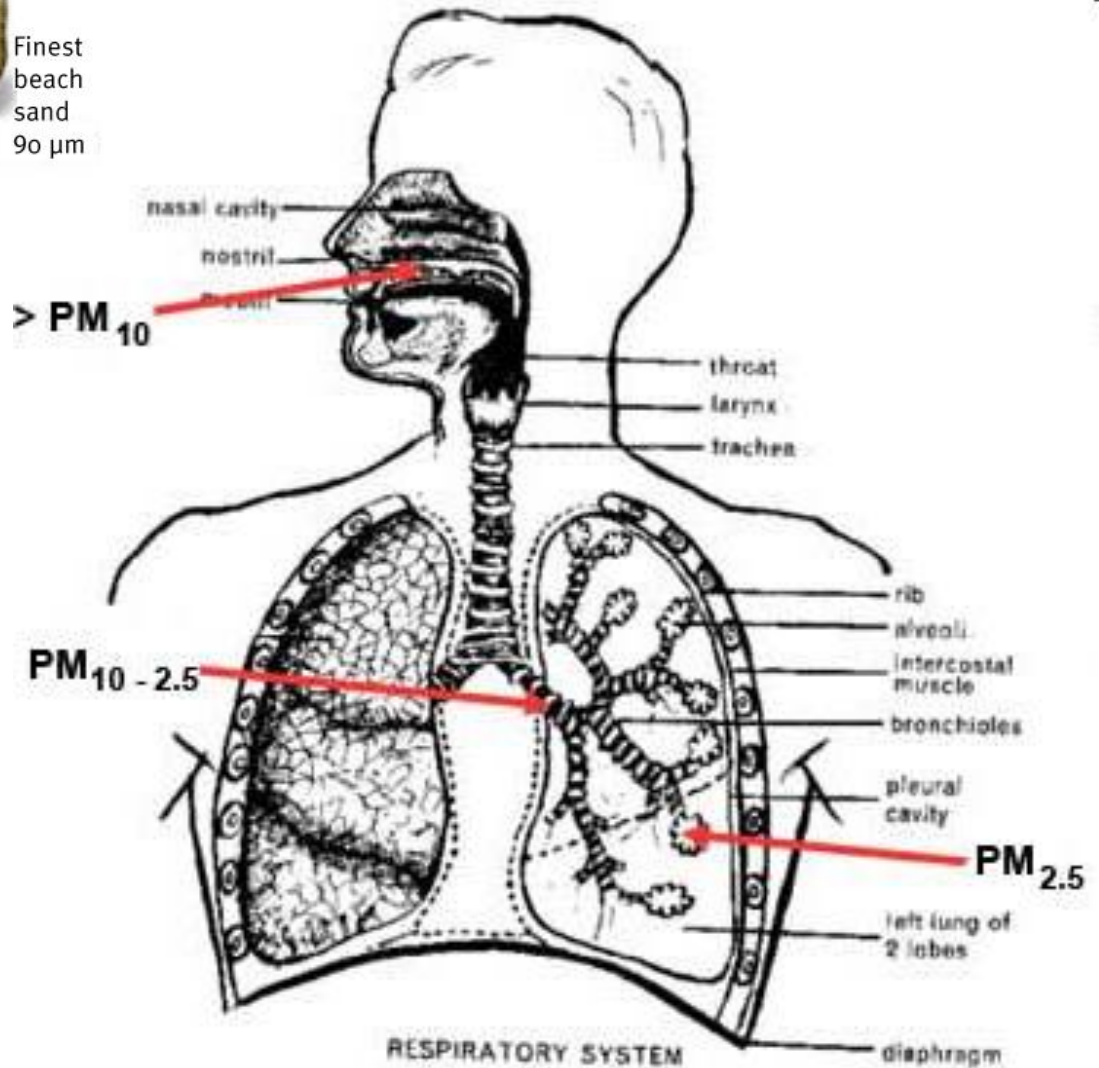
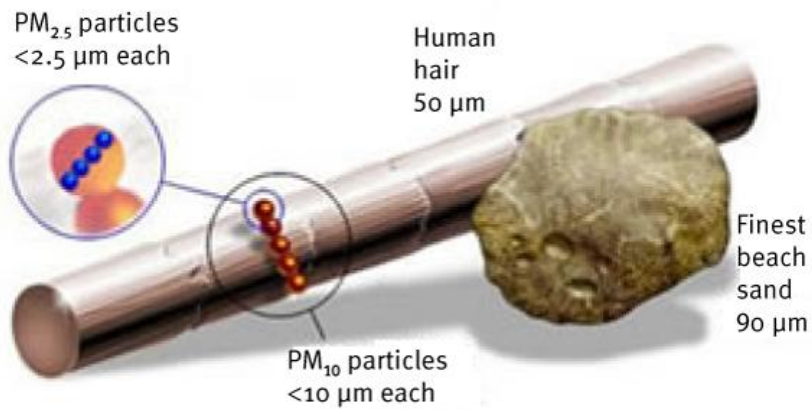
Body reacts to PM

PM contains harmful
substances

Human Health

Human Mortality





- coughing/weezing
- cause or worsen conditions
 - asthma
 - heart disease
 - chronic bronchitis
 - emphysema
 - pneumonia
- long term exposure in women
 - premature births
 - low birth weights

Source - bcairquality.ca



Total Primary, Non-renewable, Fossil Fuel Consumption

- Category indicator
 - MJ
- Characterized by (..LCI classification)
 - Athena Sustainable Materials Institute
- Includes;
 - all energy, direct and indirect, used to transform or transport raw materials into products and buildings.
 - energy contained in raw or feedstock materials that are also common energy sources.



Total Primary, Non-renewable, Fossil Fuel Consumption

	Total Primary Energy	Non-Renewable Energy	Fossil Fuel Consumption
Hydro	✓		
Non-Hydro Renewable*	✓		
Coal	✓	✓	✓
Diesel	✓	✓	✓
Feedstock**	✓	✓	✓
Gasoline	✓	✓	✓
Heavy Fuel Oil	✓	✓	✓
LPG (propane)	✓	✓	✓
Natural Gas	✓	✓	✓
Nuclear	✓	✓	
Wood	✓		

*Solar/Wind/Geothermal

**Energy stored in materials used in product

What about Resource Extraction and Land Use?





Weighted Resource Use

- Category indicator
 - kg (or kg ecological carrying capacity effect eq)
- Characterized by
 - the Athena Sustainable Materials Institute
 - Resource extraction and environmental specialists across Canada to develop subjective scores of the relative effects of different resource extraction activities.
- Midpoint impact
 - Ecological carrying capacity effects per kg extracted
 - LIMESTONE * 1.5
 - IRON ORE * 2.25
 - COAL * 2.25
 - WOODFIBER * 2.5

http://www.athenasmi.org/wp-content/uploads/2011/10/16_ECC_Impacts_of_Resource_Extraction.pdf

Weighted Resource Use

Extraction activities looked at by panel



Aggregates quarrying



Timber harvesting



Coal mining



Iron ore mining

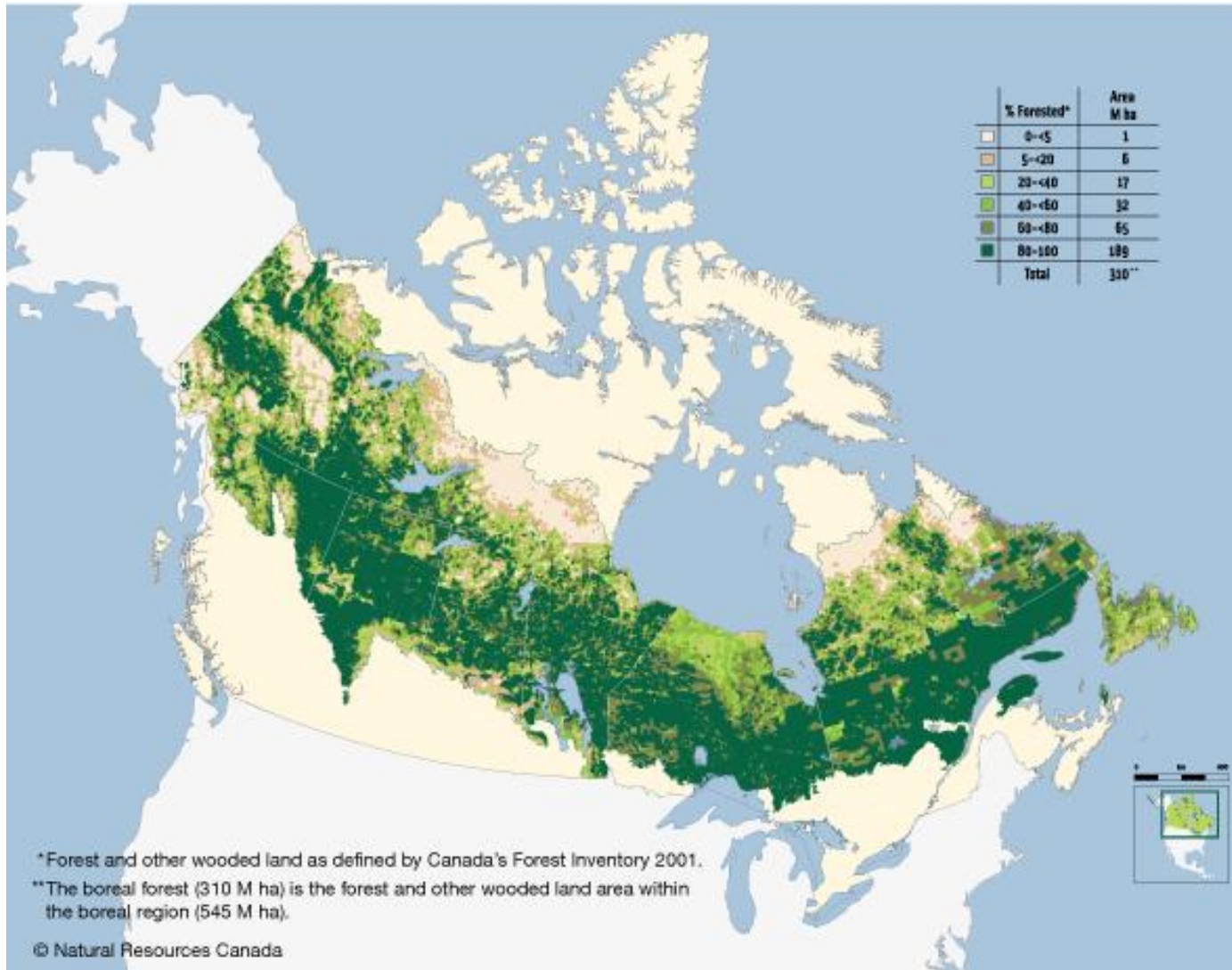


Limestone quarrying

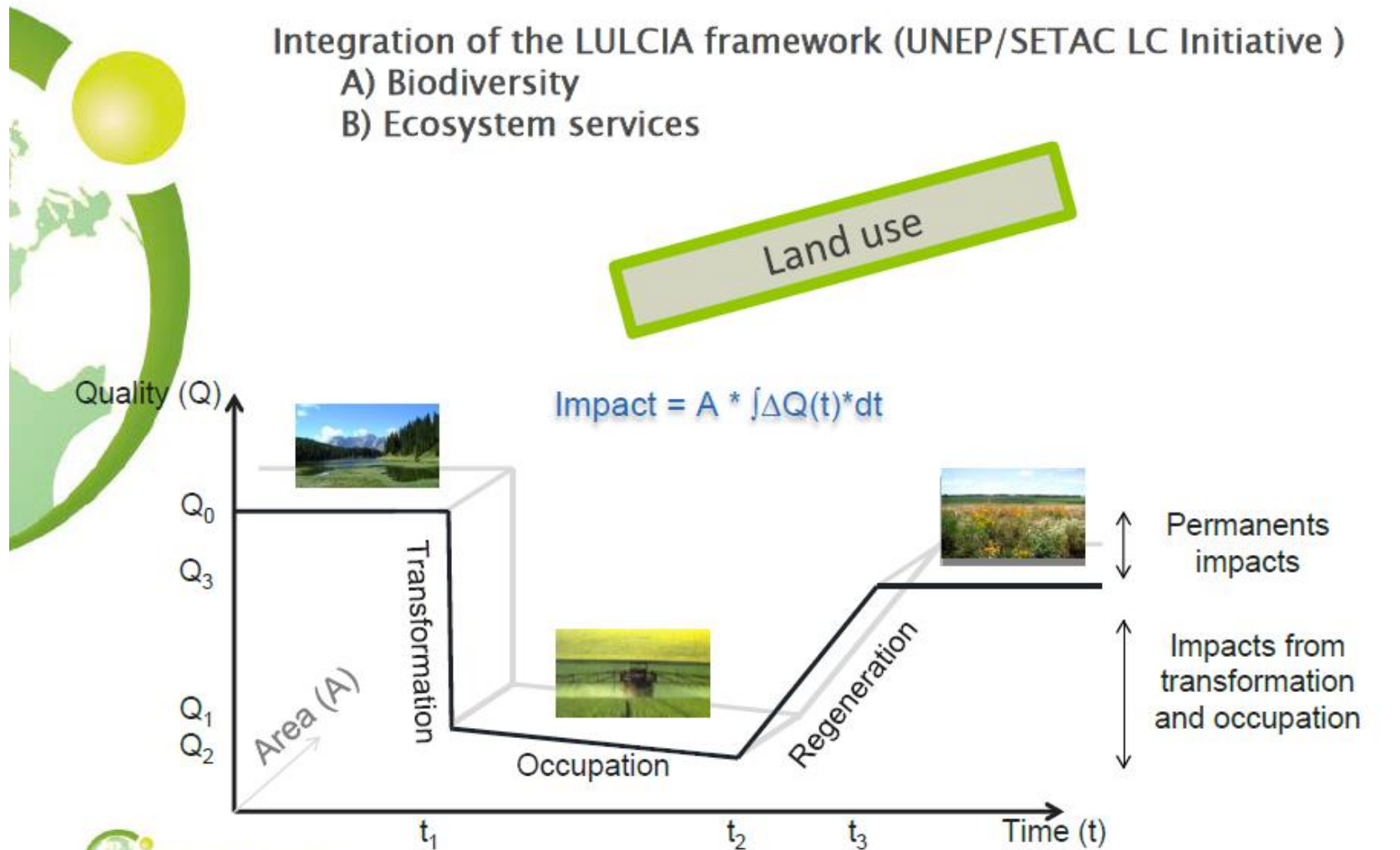
WRU - defined

- Dimensions of ecological carrying capacity impacts considered;
 - Intensity of impacts
 - How much and how long ecology disrupted
 - Extent of areas typically impacted
 - Size of area
 - Duration of impacts
 - Avg. time to return to balance
 - Ecological significance of areas typically impacted
 - Uniqueness and social value

WRU – Boreal forest



Ex. IMPACT World+ Method for Land Use change impacts



10/8/2014

IMPACT World+™

(Curve adapted from Milà i Canals et al. (2007))⁵⁵

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1. What is Impact Assessment?
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3. Impact Category descriptions.
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Keep in mind, LCA results provide a snapshot.

So, how do you interpret what you see?



Class Impact Aversion Survey

if you only had 100\$ to invest in avoiding the impacts associated with the following impact categories, where would you invest your money?

This is how we will determine which impacts matter most to the class, and how much each of them matters to the class.

*you can pocket the 100\$..

[illegible]

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Table 2.3 Overview of widely-used impact categories with examples of category indicators at Midpoint and Endpoint levels.

Impact Category	Midpoint Category Indicator	Endpoint Category Indicator
climate change	infra-red radiative forcing	loss of life years, fraction of disappeared species
ozone layer depletion	change in tropospheric ozone concentration	loss of life years
acidification	H ⁺ concentration	fraction of disappeared species
eutrophication	biomass potential	fraction of disappeared species
human toxicity (sometimes split into carcinogenics, non-carcinogenics, respiratory effects, etc.)	time-integrated exposure, corrected for hazard	loss of life years
eco-toxicity (sometimes split into aquatic toxicity, terrestrial toxicity, marine toxicity, etc.)	time-integrated exposure, corrected for hazard	fraction of disappeared species
depletion of energy carriers	primary energy requirement	decreased availability
depletion of material resources	amount of material used, corrected for availability and/or importance	decreased availability
land use impacts	amount of land occupied or transformed	fraction of disappeared species
water use impacts	amount of water used or displaced	decreased availability

where GW is the global warming score, s the substance (the different greenhouse gases), GWP_s the GWP of substance s , and m_s the emitted amount of substance s in kg. This may be further generalized as

$$I_c = \sum_s CF_{c,s} \times m_s$$

where c stands for the impact category, I represents the indicator result for category c , and $CF_{c,s}$ is the characterization that links substance s to impact

http://books.google.ca/books?id=EYp1Ld2ozbkC&pg=PA38&lpg=PA38&dq=Life-Cycle+Assessment:+Inventory+Guidelines+and+Principles+EPA/600/R-92/245+February+1993+pp.+24-25&source=bl&ots=MYi3vAvqij&sig=FdCuiOF34bHli_Ryo_Ti0ziUSZA&hl=en&sa=X&ei=aBhjUpi2JISfiALL8oCIBg&ved=0CDcQ6AEwAg#v=onepage&q&f=false